Practical Surveying IMPROVED;

OR,

LAND-MEASURING,

According to the preſent

Moſt Correct METHODS.

With the ſeveral

Inſtruments *of* Modern Practice:

Wherein are ſhewn

The Conſtruction, Uſes, and Excellency of Mr. *Siſſon*'s lateſt improved THEODOLITE, New-invented PROTRACTOR, SCALE of *equal Parts*, and SPIRIT-LEVEL.

With the *Method* of adjuſting the latter, tho' juſt put together, at any ſingle *Station*.

By WILLIAM GARDINER, *Land-Surveyor*.

LONDON:

Printed for JONATHAN SISSON, Mathematical Inſtrument-Maker to His Royal Highneſs the Prince of WALES, at the Corner of *Beaufort Buildings* in the *Strand*; and Meſſ. BETTESWORTH and HITCH, at the *Red Lion* in *Pater-noſter Row*.

M.DCC.XXXVII.


G.R.
III

To the RIGHT HONOURABLE

THEOPHILUS,

Earl of Huntingdon, *Baron* Haſtings, Hungerford, Homet, Botreaux, Molens, Moels, *and* Peverel, *&c.*

My LORD,

HAVING had the Honour to Survey and Plan *Your Lordſhip*'s Eſtates, and in the performance thereof, as I have reaſon to believe, given intire Satisfaction, both to *Your Lordſhip*, and the Tenants; depending therefore

on Your Goodneſs, I preſume to lay this Eſſay at *Your Lordſhip's* Feet, humbly hoping it may meet with Your Approbation, as my Work in the Practice has had the good fortune to do, which will very much conduce to the happineſs of,

My LORD,

Your Lordſhip's

Moſt Obedient and

Moſt Humble Servant,

William Gardiner.

THE PREFACE.

IN the following Pages I have drawn up a ſhort, yet I think compleat, Syſtem of Land-Meaſuring, *in the moſt natural Order, by the ſeveral Inſtruments in common Uſe, beginning (after ſome few neceſſary Definitions and Tables) with meaſuring by the Chain only, then by the Plain-Table, and then proceeding on to other Inſtruments, and to the Improvements made by Mr.* Siſſon, *and have ſhewn wherein his excel all others, and how a large* Manor, *or a* County, *may now be ſurvey'd and plotted much truer than any ever have been: With ſeveral Methods of taking the* Latitude *of Places, and a new Table of the* Pole-Star's *greateſt* Azimuth *in ſeveral* Latitudes, *with the Alteration*

Alteration for many ſucceeding Years, and alſo in ſeveral Parts of each Year, by the Earth's *Motion having a ſenſible Velocity compared with the Motion of* Light, *as found by the Obſervations of Mr.* Bradley, *tho' begun by the late Honourable* Samuel Molyneux, *Eſq; but each with a different Inſtrument, both of 'em contrived and made by Mr.* Graham. *See* Phil. Tranſ. *Numb.* 406.

On Levelling, *I have ſhewn how to adjuſt the New-invented Spirit-Level at once planting it, when firſt put together, with two Methods of taking the Difference of* Levels *by it, and a new Table of the* Dips *by the* Earth's Curvature.

The Methods here inſerted are of eaſy Practice, and of the greateſt Exactneſs: therefore, without dwelling any longer on Particulars, I refer the Reader to the Contents, and ſubmit the Whole to his candid Judgment.

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JONATHAN SISSON

Mathematical Inſtrument-Maker,

At the Corner of *Beaufort-Buildings,* In the *Strand, LONDON:*

MAKES and Sells large *Quadrants*, fitted with a *Teleſcope*, for taking the Declinations of the Sun, Moon, and Stars in the Meridian: and *Tranſit-Inſtruments*, for curiouſly determining their Right Aſcenſions.

Portable *Quadrants*, that have both a true Horizontal and Vertical Motion, for obſerving the Altitudes of the Sun and Stars in any Poſition, with which (having a good portable Pendulum) the Meridian, and Latitude of the Place will be readily determined; which may be of great Uſe on the *Sea-Coaſts*, and in the Survey of *Countries.*

Equal-Altitude Inſtruments, for obſerving Stars of equal Heights, with which (having alſo a good portable Pendulum) the Meridian and Latitude of the Place may be very accurately found.

Teleſcopes fitted with a *Micrometer*, for obſerving the apparent Magnitudes of the Sun, Moon, and Planets, with their different Phaſes, and the Appulſes of the Moon and Planets to the Fixt Stars.

Large *Double-Inſtruments*, containing two chief Parts connected together, and having four ſeveral Motions, all moved by Rack-Work: 1. A circular Motion to ſhew all Horizontal Angles: 2. A ſemi-

ſemi-circular Vertical Motion; 3. A circular Equinoctial Motion, or for any Plane at Right Angles to the Vertical: 4. A Motion through a Double Sextant at Right Angles to the Third, that has a refracting Teleſcope fixt to it: By this *Inſtrument* all Angles, either Horizontal, or of Elevation or Depreſſion, the Azimuth, and Altitude of any Star, the Meridian and Latitude of the Place, with the Hour of the Day and Night, are directly given; alſo the Right Aſcenſion and Declination of the Moon, a Planet, Comet, or any Star, at one Obſervation; which, if a Comet of quick Motion ſhould appear, may be repeated every five or ſix Minutes, and thereby its Path well known.

Sun-Dials for Pedeſtals in any Latitude, or Portable Ones of ſeveral Kinds, either Univerſal, or for many different Latitudes, which have ſeveral new Improvements.

Caſes of *Inſtruments*, in Silver, Braſs, Ivory, or Wood of ſeveral Sizes; containing, a *Sector*, *Scales*, *Compaſſes* proportional and others, *Drawing-Pens*, a *Protractor*, parallel *Ruler*, Gunner's *Calliper*, &c.

Curious *Barometers*, either Standard or Portable, with a ſmall Teleſcope to them; or Diagonal Ones, and others with *Thermometers*.

Spheres and *Globes* of all Kinds; *Meridian* and *Azimuth Compaſſes*; *Sea-Quadrants*, either Mr. *Hadley*'s, *Elton*'s, or *Davis*'s: And all other Mathematical Inſtruments for Sea or Land, with *Books* of their Uſes.

Practical SURVEYING

IMPROVED.

INTRODUCTION.

A Surface or Superficies is that magnitude or quantity, which is comprehended under the two dimenſions of length and breadth, without any regard to the depth, and therefore bounded by lines only; ſo when we meaſure a Field, we take it for a Surface, which the longer and broader it is, the more Acres it contains, without any conſideration to the depth or thickneſs of the Earth.

An Angle is the opening of two ſtreight lines iſſuing from or meeting in one point, which point is then called the Angle, and the degree of ſuch opening is truly the quantity of it, which being not at all changed by the length of the lines forming the Angle, is to be meaſured by the Arch they open to in the circumference of any Circle, when the Angle

itſelf is placed in or made the center, and the lines each extended to the circumference, which being divided into 360 equal parts called degrees, the number of ſuch parts contain'd in the Arch is the quantity of the Angle in degrees.

Note, Tho' every Angle is leſs than 180 degrees, yet in *Surveying* it is common to reckon the degrees of either the external or internal Arch according to which of the lines is made firſt, whereby an Angle is often taken as much exceeding 180 degrees, as the real Angle is leſs than 180.

A ſtreight Line is ſaid to be perpendicular to another, when meeting therewith, it makes the Angle on one or both ſides equal to a quadrant or quarter of a Circle; the Angles thus made are called right Angles, and the lines thus meeting, do each make the neareſt diſtance from it's farther point to the other line.

A ſtreight Line is parallel to another, when in the ſame plain Surface two or more Perpendiculars drawn from one to the other are of the ſame length; ſuch Perpendiculars are alſo Parallels to each other, and the former are Perpendiculars to theſe; all of them making the neareſt diſtance between the Parallels.

Fig. A is a ſquare Surface, contain'd within four equal Sides, whoſe oppoſites are parallel, and the others perpendicular thereto, and conſequently making the neareſt diſtance between the Parallels, and forming all the Angles right ones;

ones; the length of any Side (all being equal) in any dimenſion multiplied into itſelf will produce the Area or Quantity contain'd therein; ſo that if we ſuppoſe each Side 5 feet long, then 5 feet multiplied into 5, makes 25 for the Area of the Square; or if each Side be 5 of *Gunter*'s chains of 4 poles each, then the Area will be 25 ſquare chains equal to 400 ſquare poles, that is, 20 multiplied by 20, the length of each Side in poles.

Fig. B is a rectangular Parallelogram, and is commonly called a Rectangle or oblong Square, contain'd within four Sides, whoſe oppoſites are equal and parallel, and the others perpendicular thereto, and ſo making the neareſt diſtance between the Parallels, and forming all the Angles right ones; the length of one long Side multiplied into one of the ſhorter will produce the Area, that is, the length into the breadth; therefore if the length be 5 chains, and the breadth 2, theſe multiplied make 10 ſquare chains, equal to 1 acre or 160 ſquare poles.

Fig. C is alſo a Parallelogram, contain'd within four Sides, whoſe oppoſites are equal and parallel, but the others not perpendicular to them, and ſo not making the neareſt diſtance between the Parallels, nor forming the Angles right ones; the length of any one Side, multiplied into the neareſt diſtance between it, and the Parallel paſſing thro' it's oppoſite, will produce the Area; ſo if the length of either two oppoſite Sides be each 5 chains, and the

ſaid neareſt diſtance 2, there will be but the ſame Area as in *Fig.* B, altho' the other Sides be extended to any length poſſible.

Fig. D is a Triangle of three unequal Sides, which by *Euclid* 1. 34. is demonſtrated to be equal to half the Parallelogram, whoſe Diagonal and two Sides are equal to thoſe correſponding in the Triangle; conſequently the length of the longer Side multiplied into it's Perpendicular, or neareſt diſtance from the oppoſite Angle, produces a quantity, half of which is the Area of the Triangle; alſo if any Side be taken for the Baſe, and multiplied into half of it's Perpendicular, or neareſt diſtance of the Parallel paſſing thro' it's oppoſite Angle, the product will be the ſame Area of the Triangle.

Fig. E is a Trapezium, having four unequal Sides, which may by drawing a diagonal line from any Angle to it's oppoſite, be made into two Triangles, having ſuch diagonal for the Baſe common to both, which if multiplied into half the ſum of it's two Perpendiculars, will produce the Area of the whole Trapezium.

We endeavour to reduce all Surfaces into Trapezias and Triangles, and to caſt up their Areas by the above Rule; which being of general Uſe, will be fully ſhewn in the firſt Chapter.

To plot or lay down the Bounders of land on paper, we muſt know their Lengths and Poſitions on the land itſelf, to get which we make

make uſe of ſome Inſtruments, and others to plot them with when gotten.

Gunter's Chain is generally uſed to meaſure the Lengths of lines on the land; but the Inſtruments for taking their Poſitions are of two kinds.

With ſome the Poſition of a line is taken by the Angle, which it makes with the Meridian, uſing the Needle in the compaſs-box for the Index of it (allowing for the variation) as with the Circumferentor, and may be by all thoſe Inſtruments that have a compaſs-box to them; and the Poſition of a line thus taken is uſually called it's Bearing.

With others, and much more truly, we take the Poſition of a line, by the Angle it makes with another adjoining it, as with the Theodolite, the Semi-Circle, the Plain-Table, the Chain, *&c.*

Inſtruments commonly uſed in plotting are a Ruler, a Pointrel, a pair of Compaſſes, and a Scale for whole chains, with one ſpace having ten diagonal diviſions, thereby dividing it into 100 parts, for taking off the odd links; and this (if truly divided) may be the beſt for ſetting off the Angles, when they are meaſured on the land with the Chain only; but if the Angles are meaſured with any other Inſtrument, a braſs Scale made thin to the edges, and decimally divided cloſe to them between every longer diviſion (which longer are number'd with 1, 2, 3, 4, *&c.* for whole chains, and ſo the ſhorter diviſions for ten links each)

is much preferable to the other, both for exactneſs and expedition in ſetting off the lengths of the meaſured lines; for exactneſs, becauſe all lengths may be examined in ſeveral parts, whereas the diagonal Scale is confined to one length only; and for expedition, becauſe every length is ready without the trouble of ſetting the Compaſſes to it; alſo a Protractor (divided and number'd according to the Inſtrument uſed) muſt then be had, for ſetting off the Poſition of the lines, unleſs they are plotted on the Plain-Table.

By a Statute made the 33d of *Edw.* I. an Acre is to contain a quantity in any ſhape equal to 160 ſquare poles or perches of $16\frac{1}{2}$ feet ſquare each; and *Gunter*'s Chain is made four poles long, that ten of thoſe Chains in length carrying one in breadth may be an Acre, that is, four times forty ſquare poles; ſo that if a rectangle Acre be in length

Chains		*Links*
10	it's breadth muſt be	100
9	. . . . .	111,111
8	. . . . .	125
7	. . . . .	142,857
6	. . . . .	$166\frac{2}{3}$
5	. . . . .	200
4	. . . . .	250
3	. . . . .	$333\frac{1}{3}$
2	. . . . .	500
1	. . . . .	1000

A Table of Meaſures for Lines *and* Squares.

In length one	*Link,*	*Foot,*	*Yard,*	*Pole,*	*Chain*
In one ſquare	*Inches*	7,92	12	36	198	792
Link	62,7264	*Links*	1,51515	4,54545	25	100
Foot	144	2,29568	*Feet*	3	16,5	66
Yard	1296	20,66116	9	*Yards*	5,5	22
Pole	39204	625	272,25	30,25	*Poles*	4
Chain	627264	10000	4356	484	16	*Cha.*
Acre	6272640	100000	43560	4840	160	10

Note, Every Table that I have ſeen, errs in the *Links* contain'd in a *Yard*, both in length, and it's ſquare.

A Table for changing Foot-Meaſure *into Links and Decimals*, & è contra.

Feet	*Links*	*Feet*	*Links*	*Links*	*Feet*	*Links*	*Feet*
1=	1,51515	10=	15,1515	1=	0,66	10=	6,6
2=	3,03030	20=	30,3030	2=	1,32	20=	13,2
3=	4,54545	30=	45,4545	3=	1,98	30=	19,8
4=	6,06061	40=	60,6061	4=	2,64	40=	26,4
5=	7,57576	50=	75,7576	5=	3,30	50=	33,0
6=	9,09091	60=	90,9091	6=	3,96	60=	39,6
7=	10,60606	70=	106,0606	7=	4,62	70=	46,2
8=	12,12121	80=	121,2121	8=	5,28	80=	52,8
9=	13,63636	90=	136,3636	9=	5,94	90=	59,4

Note, This Table may be extended to hundreds or thouſands of *Feet* or *Links* by removing the comma one or two places to the right hand in the tens of *Links* or *Feet*; and if in thoſe anſwering units, it be removed one place to the left, they will be equal to tenths of a *Foot* or *Link*.

CHAP.

CHAP. I.

Shewing how to meaſure a Field or other piece of land by the Chain only.

Sect. 1. *Shewing how to meaſure a Line with the Chain.*

THE Chain contains in length 4 poles or 66 feet, divided into 100 links, each link with the rings between being 7,92 inches, having pieces of braſs of different ſhapes at the end of each ten links, and braſs rings at every five, for the ſpeedier counting the odd links.

We commonly have an Offset-Staff of 79,2 inches long, equal to ten links on the Chain, divided into ten equal parts, each part is a link, and ten times this Staff the whole Chain.

We have alſo ten arrows or ſmall ſtreight ſticks near two feet long, with bits of bright ſcarlet cloth fixt in at the tops, and ſhod with iron ferrils at the bottoms.

At firſt opening the Chain to meaſure with, I always examine it, (leſt any of the rings ſhould be got one in another, whilſt it is lapt up, and the Chain thereby ſhorten'd) which is readily done by the Offset-Staff as it lies ſtretcht

ſtretcht in the firſt line, and hereby I am ſenſible of every little increaſe of the Chain by often ſtretching, and can ſhorten it accordingly; for which cauſe as well as it's better playing, every Chain ſhould have three rings between each link; then the braſs marks may be on the middle rings, and ſo their diſtances the more equal.

The Chain being of it's juſt length, I cauſe the Leader to ſtick in the ground one of the ten arrows (which he is always to have at firſt ſetting out) at the far end of the Chain, whilſt the near end touches the place I meaſure from, and as exact as poſſible in the line to the place I am meaſuring to; then the Leader leaving the arrow proceeds on with the Chain another length, and whilſt I hold my end to touch the firſt arrow, I cauſe him to ſtick down another at his end, always as upright and exact in the line as poſſible, which he may now judge of, by reaſon he muſt ſtick down the ſecond, and all the following arrows, in ſuch manner that the next foregoing may be in the line between it, and the place we meaſure from; and thus we proceed till the Leader arrives at the place we are meaſuring to, which ſuppoſe leſs than a Chain from the laſt arrow ſtuck down, the Leader holding his end to the place, whilſt I hold the Chain where it touches the laſt arrow, then I ſoon diſcover by the braſs marks the odd links, which either added to the number of Chains as decimals, or wrote down as links with the Chains in hundreds place, will be the

length of the whole line; as for the Chains, they are known by the number of arrows which I arrive at, and take up; ſuppoſe I am at the ninth arrow, and that the links over are 70, I write it down 970, denoting thereby ſo many links; if it is but 7 links over the nine Chains, I write it 907, becauſe every Chain is 100 links.

When the Line is above eleven Chains, I cauſe the Leader (when at the eleventh) to put down the Chain end, while ſtretcht in the line, as before; but having no arrow, he ſets his foot thereon to keep it from ſhrinking back, whilſt I bring up to him the ten arrows, and ſtick one down at the Chain end, giving him the other nine, which it muſt always be minded he has to go on with from the eleventh to the twelfth Chain; and the like again, if the line ſhould be above 21 Chains, and alſo if above 31; for always at ſetting out, and at giving up the arrows, whether as above, or at the end of each line, I mind there are in all ten arrows.

Sect. 2. *Shewing how to meaſure a Field whoſe quantity of Acres is wanted without any Plan of it.*

Let *Fig.* F be the Field to be meaſured.

Firſt, I walk about it, and ſet up ſtreight ſticks of 3, 4, 5, or 6 feet long (as needful) with a ſlit at top, and white paper therein, which I call objects, in all the angles or cor-

corners of the Field; judging the line *a e* moſt convenient for the Diagonal, I ſet up objects alſo exactly in the ſame as at *m* and *q*; for if I ſtand at *a* looking at *e*, I can direct my Aſſiſtant to place thoſe two objects exactly in the line *a e*, and my Aſſiſtant can judge of their being near *m* and *q*; but I can remedy that, if need be, and by them keep truly in the line throughout.

The objects being all ſet up, and being at *a*, I begin there to meaſure the diagonal line *a e*, in meaſuring which I find *m*, *viz.* 276 links from *a*, ſeems to be the neareſt place in the line *a e* to the angle *b*; therefore before I meaſure any farther than the third arrow already ſet down, I meaſure the Perpendicular *m b* 524 links, and write it down in my field-book, then I come back to the third arrow left ſtanding in the line *a e*, and meaſuring on farther towards *e*, I find *q* at 932 links from *a*, where the angle *b* is perpendicular to *a e*, then I meaſure *q b* 538 links, and write it under the 524; then coming back to the tenth arrow, I meaſure on to compleat the whole line *a e*, which being 1247 links, I write it down as a Multiplicand, and half the ſum of the two Perpendiculars already wrote down I ſet under it for a Multiplier, the product of which will be the Area of the large Trapezium *a b e h* in ſquare links.

Note, Some may judge that I am liable to much error in miſſing the true places of *m* and *q*; therefore I ſhall juſt mention that I

have the ſpace of 45 links for taking each, without having the Perpendicular increaſed half a link, which if both were, would not increaſe the Trapezium one ſquare pole.

From *e* I meaſure in a ſtreight line towards *c*, and find *r*, where the angle *d* is perpendicular, then meaſuring *r d* 360 links, half of which I ſet down as a Multiplier under 657, the length of the whole line *e c*, their product is the Area of the Triangle *c d e.*

I begin again at *e*, and meaſuring towards *g*, find *p* the neareſt place in the line *e g* to *f*, then meaſuring *p f* 97 links, I ſet it down as a Multiplier under 189, half the length of *e g*, the product is the Area of the Triangle *e f g.*

Now I begin at *i*, and meaſuring towards *l*, find *n*, where the angle *k* is perpendicular, then meaſuring *n k* 425 links, I ſet it down as a Multiplier under 747, the whole length *i l*, half the product is the Area of the Triangle *i k l.*

Now the ſum of theſe four Areas is the Area of the whole Field in ſquare links, 100000 of which make one acre; therefore we can ſee the number of acres at firſt ſight, becauſe it is the figure or figures on the left hand of the five right hand figures to be cut off; for that is, according to the Rule in vulgar Arithmetick, dividing by 100000 the ſquare links in an acre, which in this Example gives 9 acres for the quotient, and the 57487 cut off are the remainder, and are decimals of an acre, which multiplied by 4, the roods in an

acre,

acre, gives the odd 2 roods, with the five right hand figures 29948 for decimals of a rood, and theſe multiplied by 40, the poles in a rood, gives 11 poles, with 97920 decimals of a pole, which being near an Integer, the Area of the whole Field may be reckon'd 9 *a.* 2 *r.* 12 *p.* See the following Work, where the five right hand figures are ſeparated by a comma, as it is uſual in decimals.

1247	657	189	747
531	180	97	425
1247	52560	1323	3735
3741	657	1701	1494
6235			2988
662157 = *abeh.*	118260	18333	317475
118260 = *cde.*			2)
18333 = *efg.*			158737
158737 = *ikl.*			

a. r. p.

9,57487 = - - - - 9 : 2 : 12 nearly.

4

2,29948 = $2\frac{29948}{100000}$ roods.

40

11,97920 = $11\frac{97920}{100000}$ poles.

Note, It is the common practice of moſt Surveyors to multiply the whole Baſe by the whole Perpendicular in every Triangle, and by

by the ſum of the two Perpendiculars in every Trapezium, and to halve the ſum of all the Products after they are added together, which I ſhould have done in this Example, had I not choſen to have ſhewn that it is indifferent which method is uſed, either halving the Baſes, Perpendiculars, or Products; tho' the laſt is moſt eligible, when ſeveral of them are added together.

Sect. 3. *Shewing how to meaſure a Field of which a Plan is required, as well as the quantity contain'd in it.*

Let *Fig.* F be the Field to be meaſured and plotted.

Having ſet up objects as before in all the angles, and being at *b*, I begin with meaſuring *b a*, 592 links, and write it down in my field-book, then I meaſure *a e* 1247, as before, and write that down alſo; then I meaſure from *e* towards *b*, and write that at 657 it toucht the bounder as at *c*, with continuance, then the whole of *e b* 1103 links; then I go back to *c*, and meaſure *c d* 384, and *d e* 636, writing them down alſo; then I meaſure from *e* towards *h*, and write that at 274, as at *p*, the offset is 97 links to *f*, alſo that at 378 it toucht the bounder at *g* with continuance, then the whole of *e h* 623; then I meaſure from *h* towards *a*, and write that for 213 it toucht the bounder to *i*, and then left it, and at 960 it toucht the bounder again at

at *l* with continuance, and the whole of *b a* 1075; now returning to *l*, I meaſure *l k* 466, and *k i* 699, writing them down alſo; and thus the meaſuring in the Field is compleated.

In meaſuring a Field thus, I ſhould take a ſketch of the ſeveral lines meaſured, and write thereon their lengths, as I have done in *Fig.* F, for I have not propoſed this in a regular method, but for diſpatch, and a make-ſhift for a ſingle Field, where I have no other Inſtrument but the Chain, and the whole length of *a e* can be ſeen, and the like of the other lines.

To plot this upon paper, I firſt draw with a fine ſteel Pointrel a dry or obſcure line for the Diagonal *a e*, and by a Scale of equal parts (ſuch as before adviſed) laid thereto, I meaſure 1247 links, and make fine point-holes for the angles *a* and *e*; then with a pair of Compaſſes having fine points, I take on the ſame Scale 592, the length of *b a*, the ſhorter line, and with one foot in *a*, I deſcribe a ſmall arch for *b*; then by the edge of the Scale I ſet off from *e* 1103, the length of *e b*, making in the ſmall arch a fine point-hole for *b*, and draw a dry line for *e b*, in which I ſet off from *e* 657 for *c*; then with my Compaſſes I take 384 for *c d*, and with one foot in *c*, I deſcribe a ſmall arch for *d*, then with the Scale I ſet off therein from *e* 636, the length of *d e*; then I draw black lines for the bounders *a b*, *b c*, *c d*, and *d e*.

Now

Now I take with my Compaſſes 623 for *eh*, and with one foot in *e*, deſcribe a ſmall arch for *h*, then with the Scale I ſet off therein from *a* 1075, the length of *ha*, and draw dry lines for *eh* and *ha*; in *eh* I ſet off from *e* 274 for *p*, and 378 for *g*; then turning the Scale perpendicular to the line *eh* at *p*, I ſet off therefrom 97 for *f*; now laying the Scale to *ha*, I ſet off therein from *h* 213 for *i*, and 960 for *l*; then taking with my Compaſſes 466, with one foot in *l*, I deſcribe a ſmall arch for *k*, and with the Scale ſet off therein from *i* 699, the length of *ki*; now I alſo draw black lines for the bounders *ef*, *fg*, *gh*, *hi*, *ik*, *kl*, and *la*, and thus the plotting of the rough Plan is finiſht; as to fair ones, I ſhall treat of them hereafter.

Note, Fields thus plotted by the meeting of meaſured Lines are plotted neareſt truth, when thoſe Lines make at their points of meeting Angles neareſt approaching to right ones.

To meaſure the quantity in the Plan, we take the ſame method as in meaſuring in the Field for the quantity only, if meaſuring with the Scale in the Plan be allowed inſtead of meaſuring with the Chain in the Field; for the Plan is already divided into the ſame Trapezium and Triangles as the Field was, and the Scale will meaſure the ſame Baſe-lines, tho' in this three of them are directly given for the Baſes of the Trapezium and two Triangles, and ſubſtracting *hi* from *hl*, there will remain

il,

i l, the Baſe of the other Triangle; but I muſt meaſure the Perpendiculars by the Scale, for which uſe it is very ready, as well as to ſet them off with in plotting; if the lines on the paper by the difference of weather be alter'd, I allow in proportion for each; becauſe if it is not caſt up for the quantity immediately after plotting, there may be a perceptible difference on that account.

The Baſes and Perpendiculars in the large Trapezium and three Triangles of *Fig.* F, are as before, therefore I ſhall not repeat what is ſaid already.

Sect. 4. *Shewing the Method of reducing a multangular Figure to one Trapezium.*

Let *Fig.* G be the Figure to be reduced to one Trapezium.

Firſt, I extend one of the ſides as *a g*, by drawing a dry line produced both ways, if needful; then laying the edge of a parallel Ruler to the angles *a* and *c*, I move it parallel till it touches the angle *b*, then I make a fine point-hole cloſe to the Ruler-edge in the extended line at *y*.

Now laying the edge of the Ruler to *y* and the angle *d*, I move it parallel to touch the angle *c*, and make a fine point-hole cloſe to the edge in the extended line at *z*, and draw a dry line *z d* for one ſide of the Trapezium.

Now laying the edge of the Ruler to the angles *g* and *e*, I move it parallel to touch the

angle *f*, and make a fine point-hole in the line *ag* at *x*, and draw a dry line from it to *e*; and thus the ſeven-ſided Figure *abcdefg* is reduced to the Trapezium *zdex* equal thereto.

The line *ex* being the diagonal of the Parallelogram *xheg* by *Euclid* 1. 34. divides it into two equal parts, juſt as *ef* does one part, and *fg* the other; alſo the Triangles *efg* and *exg* are equal by *Euclid* 1. 37. as having the ſame Baſe *eg*, and being between the ſame Parallels; therefore the line *ex* takes in exactly equal to what it caſts out.

Alſo the line *cy* divides the whole Parallelogram *ykca* equally, as *cb* does one part, and *ba* the other; and the line *dz* divides *zldy* equally, as *dc* does one part, and *cy* the other; therefore the line *dz* takes in equal to what it caſts out; and in this manner may any multangular Figure be reduced to one Trapezium or Triangle; either of which may be caſt up into ſquare links by one multiplication, and ſo is not only more expeditious, but alſo free from the many miſtakes, which often are made in many ſmall Triangles.

If I have not a parallel Ruler, I lay the edge of a common Ruler to the angles *a* and *c*, and with my Compaſſes take the neareſt diſtance from the Ruler-edge to the angle *b*, and the ſame diſtance gives *y* in the extended line, and ſo of the reſt; but then I mind to ſet it off perpendicular to the edge of the Ruler.

Let

Let *Fig.* H be a twelve-ſided Figure to be reduced to one Trapezium.

Firſt, I extend one of the ſides, as *a b*, by producing it with a dry line to *o*, then laying the edge of a parallel Ruler to *b* and *d*, I move it parallel to touch *c*, and it cuts the produced line at *n*; then laying the edge to *n* and *e*, it touches alſo *d*; now laying the edge to *n* and *f*, I move it parallel to *e*, and it cuts the produced line at *o*; then laying the edge to *o* and *g*, I move it parallel to *f*, and it cuts the produced line at *p*; now I draw a dry line from *p* thro' *g* produced to *r*.

Now laying the edge to *g* and *i*, I move it parallel to *h*, and it cuts *p g* produced at *r*; then laying the edge to *r* and *k*, I move it parallel to *i*, and it cuts *p g* produced at *s*; then I draw a dry line from *s* thro' *k* to *x*.

Now laying the edge to *k* and *m*, I move it parallel to *l*, and it cuts *s x* at *x*; then laying the edge to *x* and *a*, I move it parallel to *m*, and it cuts *s x* at *z*; now drawing a dry line from *a* to *z* compleats the reduction of the twelve-ſided Figure to one Trapezium equal thereto, whoſe Area in ſquare links is had by one multiplication.

Where the bounder of a Field has ſeveral ſmall and ſhort bends, I lay a fine ſilk or thread from the angle at one end thro' the ſeveral irregularities, making a fine point-hole, that a dry line drawn from the angle to the fine hole may leave out equal to what it takes in; for ſuch ſmall quantities may by

this means be judged of nearly by ſight: but Mr. *Siſſon* makes a braſs bow ſtrung with a hair or fine ſilver wire for this purpoſe.

Sect. 5. *Shewing how to meaſure Angles with the Chain, and to plot a Field or a Wood thereby.*

Firſt, I take care that the mark in the middle of the Chain, and thoſe at every tenth link be each at equal diſtances; indeed every link ſhould be exact; but for them I have my Offset-Staff of ten links long divided into links and decimals, that is, into 100 equal parts, ſuch as the Chain contains 1000.

Let the Angles of *Fig.* I be the Angles to be meaſured and plotted; and firſt the Angle *a*.

I ſet objects exactly upright at *b* and *q*, and an arrow at *a*, and hold one end of the Chain to touch it, whilſt I direct an Aſſiſtant with the other end in his hand to ſet up an arrow at that end directly in the line towards *b*, as at *d*; then I direct him to do the ſame alſo exactly in the line towards *q*, as at *e*; then I meaſure the chord-line *de* 92½ links, and write them down in my field-book 925 parts, ſuch as my Offset-Staff is divided into.

To plot this Angle, I draw a dry line for *a q*, and make a fine point-hole for *a*; then I take with my Compaſſes off my Scale of equal parts the length of ten chains, and with one foot in *a*, I deſcribe the arch *e d f*; then laying

laying the edge of my Scale to *e*, I ſet off in this arch *d* at 925 links from *e* for the chord-line *de*; then drawing the line *ad* plots the Angle *a*.

To meaſure the Angle *b*, I ſet up objects at *a* and *c*, and an arrow at *b*, and hold one end of the Chain to it, directing an Aſſiſtant to ſet up another at the other end, as before, in the line towards *c*, as at *i*, and the like in the line towards *a*, as at *x*; now whilſt two Aſſiſtants hold the Chain ſtreight in this laſt poſition to touch both arrows, I ſet up another at the middle mark, as at *h*; then the Aſſiſtant at *x* brings his end to *h*, whilſt I bring the middle to *o*, and ſet up there alſo an arrow, forming the equilateral Triangle *hbo*; then bringing the end of the Chain from *h* (whilſt the other remains at *b*) into *bo* produced, I ſet up alſo an arrow at *e*, the Chain's whole length from *b*, thereby making the equilateral Triangle *xbe*; now I try if *xe* be truly a chain, or make it ſo; becauſe half a chain is too ſmall a length to depend on in meaſuring Angles; then I meaſure *ei* 807 parts, to be added to one ſextant, or chord of a ſixth part or 60 degrees, which in every Circle is equal to the radius or ſemi-diameter; and I write them 1. 807, meaning 1 ſextant and 807 parts.

To plot Angle *b*, I draw a dry line for *ab*, and make therein *b*; then I take with my Compaſſes ten chains as before, and with one foot in *b* deſcribe the arch *xeil*; then with one foot

foot in *x*, I ſet off the 1 ſextant at *e*; now laying the Scale to *e*, I ſet off 807 links for another chord-line extending to *i*; then drawing *b i* plots the Angle *b*.

Note, If from *e* I ſet off 517 $\frac{6}{10}$ in the arch for the ſecond chord-line; then a line drawn to it from *b*, would make at *b* a right angle; thus I may raiſe a perpendicular at the end of a line without a Protractor; and as all parts may be ſuppoſed the end, therefore it may do for any part. Alſo hereby a right angle may be ſet off on the land with the Chain only.

To meaſure the Angle *c*, I ſet up objects at *b* and *d*, and an arrow at *c*, and others at *r* and *k*, one chain's length in both lines, and alſo at *t* and *u*, half a chain from *c*, and another at *m*, as in meaſuring Angle *b*; then my two Aſſiſtants holding the ends of the Chain, one to *u*, and the other to *c*, I bring the middle to *o*, making another equilateral Triangle of half a chain each ſide; then I take the end from *u* to *p*, and ſet up an arrow there alſo; now I meaſure the lengths *k m*, and *m p*, and if not exactly a chain each, I make them ſuch, and then I meaſure *p r*, the chord-line to be added to the two ſextants, and write down 2. 793, meaning 2 ſextants and 793 parts.

To plot Angle *c*, I draw a dry line for *b c*, and make therein *c*; then I take with my Compaſſes ten chains as before, and with one foot in *c* deſcribe the arch *k m p r q*; then with

with one foot in *k* I ſet off *m* for the firſt ſextant, and *p* for the ſecond; now laying the edge of the Scale to *p*, I ſet off 793 links for the third chord-line to *r*; then drawing *c r* plot the Angle *c*.

Note, If with the Compaſſes having the extent of about 707 links, I firſt with one foot in *m* deſcribe the ſmall arch *e a*, and next with the ſame foot in *p* deſcribe the other ſmall arch *y z* to croſs it; a line drawn from *c* to the interſection makes at *c* a right angle, and is a better way for raiſing a perpendicular at the end of a given line, when the paper will allow it; the Compaſſes may have any extent for the radius and two ſextants, ſo that for deſcribing the ſmall arches be near $\frac{3}{100}$ leſs.

The Angle *d* may be meaſured and plotted like *b*, and the Angles *e* and *g* as *c*; but I muſt ſhew how to meaſure and plot the external Angle *q*.

Note, When ſeveral angles are in one point, it is uſual to diſtinguiſh each by three letters, of which the middle letter ſhews the angle, and each of the others, with the middle one, the lines forming it; as the angle *g q a* or *a q g* is the angle, which the lines *g q* and *q a* form at the point *q*.

To meaſure the Angle *q*, I ſet up objects at *g* and *a*, and an arrow (or higher object, if needful) at *q*, and another at one chain towards *a*, as at *n*; then whilſt an Aſſiſtant holds one end of the Chain at *q*, I take the other end in my hand, and ſet up another

arrow

arrow in the line *g q* produced, as at *s*; then the chord-line *n s* meaſures the Angle *n q s*, like as *d e* does the Angle *a*; as plotting *n q s* from *g q* produced is like plotting the Angle *a*, I only mention that in writing it down, I add 3 ſextants to the meaſure, to ſhew it an external Angle.

Note, In practice I would produce the longer line; for *a q* may be more truly produced to *u*, than *g q* to *s*; and the Angles *g q u* and *a q s* are equal. *Euclid* 1. 15.

The manner of meaſuring the lines on the land, and plotting their lengths, is the ſame as in *Fig.* F, except that here they are meaſured ſucceſſively as I go round in the Field; but as theſe lines may have offsets taken from them to the bounders, I muſt refer the Reader to the next chapter, where I ſhall be more particular in that part, when treating of the Plain-Table.

Let *Fig.* I now be a Wood, that I muſt meaſure round on the outſide, and plot, having only the Chain to meaſure with on the land, and that I may begin with the Angle *e*.

It has been proved, that the Angles *g q u* and *a q s* are equal, and by the ſame *g q a* and *u q s* are equal; conſequently the Angles *z e f* and *d e g* are equal; but it is eaſier to meaſure and plot the Angle *g e f*, like as the Angle *q* was for the inſide; ſo that it is apparent the Chain will meaſure the Angles without the Field as well as within; but other Inſtruments being

being more ready in practice, I ſhould now proceed to the Plain-Table.

But as it may often be wanted to have a right Angle ſet off on the land by the Chain only, both where a ſtreight line can't be produced, and where it can; I ſhall ſuppoſe *q* in the line *ae* of *Fig.* F, the place; and firſt where the line can be produced; then I meaſure any length between 30 and 40 links towards *a*, and exactly the ſame length in the line *aq* produced towards *e*, ſetting up an arrow at each; then whilſt my two Aſſiſtants hold the Chain ends to the two arrows, I take the middle towards *h*, and equally ſtretch it from both ends, whereby I have a perpendilar from the line *ae* at *q*, and a line from it to *q*, will make at *q* two right Angles.

But if *aq* could not be produced towards *e*, I meaſure 80 links towards *a*, then I meaſure 60 links, as nearly perpendicular as I can gueſs, ſetting up an arrow at each; then I meaſure the diſtance between the two arrows, and if not exactly a chain, I make it ſuch, by moving the laſt arrow farther, or nearer; but I take care it ſtill be exactly 60 links diſtant from *q*, and then it will be a perpendicular to the line *aq* at *q*, and a line from it to *q* will make at *q* a right Angle; or I can do it by firſt ſetting off a ſextant, and then another chord-line of 51,76 links at a chain diſtance from *q*. See the Note *page* 22.

Let it be required to ſet out on the land a given quantity of acres in a Rectangle, of which one Side is given.

I firſt add five cyphers to the right hand of the given acres, which make them ſquare links; then I divide them by the links in the given Side, the quotient is the length of the other Side or Perpendicular in links alſo, which length I ſet off at right angles to both ends of the given Side; now a ſtreight line from the farther end of one Perpendicular to that of the other, will be equal to the given Side, and theſe four lines will form a Rectangle, and encloſe the quantity required.

But if the given quantity has odd roods and poles, I add for every rood 40 to the poles, and four cyphers to the right hand of the ſum; then I divide it by 16, and the quotient is ſquare links, which I annex to the acres inſtead of the five cyphers.

CHAP.

CHAP. II.

Shewing how to meaſure a Field or other piece of land by plotting it on the Plain-Table.

Sect. 1. *Shewing how to plot any piece of land at one Station, from whence all the angles can be ſeen and meaſured to, and to divide and caſt up the ſame.*

LET *Fig.* K be the Field to be plotted and meaſured.

Firſt, I go round and ſet objects upright in all the angles, then I plant my Plain-Table, if poſſible, where I can ſee them all; and if in any place a nearer object will be in the ſame line as a farther, I chuſe it; finding at ⊙ that *g* coincides with *h*, and *c* with *b*, I plant there my Table, and fix paper thereon, and make the length way of it correſpond to that of the Field.

Now I make on the paper a fine point-hole with a ſmall black-lead circle round it, as at ⊙, to repreſent the place of the Table on the land, and apply the edge of the Index-

ruler thereto, ſo as thro' the ſlit to ſee the object at *a* cut by the hair in the midſt; then with my Pointrel by the edge of the Index-ruler, I draw a dry line from the fine hole at ⊙ towards *a*; then I do the like in viewing to *c*, *d*, *e*, *f*, and *g*, keeping the edge cloſe to ⊙, and drawing dry lines from it towards all of them.

Now by a plumb-line I find the place on the ground under ⊙ on the paper, where I make a hole, and from it meaſure the diſtances, firſt to *g*, and proceed on in the ſame line to *h*, writing down their lengths as I come to each; then I go to *a*, and meaſure from it to ⊙; then with my Scale (as large as the paper will allow) I ſet off in the dry line drawn towards each it's diſtance; then I meaſure to *c*, and continue on the line to *b*, and ſet off their diſtances; then I meaſure from ⊙ to *d*, and from *e* to ⊙, and laſtly from ⊙ to *f*, and ſet off their diſtances; then I draw lines for the bounders with ink from each angle to the next in my Plan, and a line croſs the whole or part for a Meridian, parallel to the Needle in the compaſs-box, except what I allow for the variation.

Now if we imagine the paper on the Table to be the ſurface of the land, and the dry lines drawn, and meaſured lengths ſet off therein, the lines meaſured on the land, we ſhall alſo conceive the black lines drawn for the bounders, truly to agree with thoſe of the Field, and that their lengths, and all to be drawn

for

for the baſes and perpendiculars of the Trapezias and Triangles, in meaſuring for the quantity, have the ſame proportion as the Scale to the Chain, and will meaſure the ſame as if on the land itſelf, like *Fig.* F.

Fig. K may either be reduced into one Trapezium, or divided into three, whoſe baſes each being multiplied into the ſum of it's two perpendiculars gives the double Area in ſquare links, and the three products added and halved is the Area of the Field in ſquare links, which may be reduced into acres, roods, and poles, as afore taught, *page* 13. tho' a little practice will ſoon render the *Surveyor* able to diſcover at ſight the roods and poles in any decimal parts of an acre.

Fig. K may be ſuppoſed two Fields, and the Table planted in the North-eaſt angle of the lower Field, where the other angles of both might be obſerv'd, and meaſured to; alſo any of the angles may be ſuppoſed a fit place for next planting the Table to obſerve new angles for plotting any adjoining Field: the manner of removing the Table from one ſtation to another, ſhall be ſhewn in the next ſection.

Sect. 2. *Shewing how to plot any piece of land on the Plain-Table, by meaſuring round within it, or without, and taking offsets to the bounders.*

Let *Fig.* L firſt be a Field to be plotted by meaſuring round within it.

Note,

Note, ⊙ repreſents a Station, or place of planting the Inſtrument, whether Plain Table, Theodolite, *&c.* the prick-lines leading from one Station to another, are the Station-lines; the black-lines the bounders; the prick-lines from the Station-lines to the bounders, the offsets to them; and thoſe from the Stations to any angles in the bounders, the by-angles obſerv'd, which may alſo have offsets from them to the bounders.

Suppoſe I enter the Field *Fig.* L near ⊙ 2, and judging ⊙ 2 a fit place, I make a round hole in the ground, and ſet up an object in it, with the white paper exactly over the hole by means of my plumb-line; then I go round, and do the like at all the other Stations, except ⊙ 1, where I firſt plant my Plain-Table, and fixing paper thereon, turn the Table to have the length correſpond to the Field, and ſo ſcrew it faſt.

Now I make the fine point-hole for ⊙ 1 on the paper, where moſt likely to bring the whole Plan, if not too large, into one ſheet; then laying the edge of the Index-ruler to it, I view the object at ⊙ 6, and draw a dry line from it towards ⊙ 6; then turning the Index about, I next view a tree near the middle of the Field, and then the object at ⊙ 2, drawing a dry line from ⊙ 1 towards each; then I write down the degree the North end of the Needle points to, becauſe it ſhould point to the ſame at all the Stations; now I dig alſo a round hole in the ground under ⊙ 1 in my Plan,

Plan, and taking up my Table I ſet up an object in it exactly upright, and meaſure from it towards ⊙ 2, and find that perpendicular againſt 218 the offset to the angle at the bounder is 157 links, which I ſet off in my Plan like the angle *f* of *Fig.* F, *page* 16. then meaſuring on at 375 the offset is but 6, and continues the ſame to 698, at both which I ſet off 6 in my Plan; then I meaſure on to ⊙ 2, and find the whole 1041 links, which I ſet off in the dry line drawn for it, and mark it ⊙ 2; then taking out the object, I plant my Table to have ⊙ 2 over the hole, when placed parallel to what it was at ⊙ 1; that is, the edge of the Index-ruler touching both Stations, the hair muſt cut the object at ⊙ 1, and ſo I ſcrew it faſt.

Now ſetting up objects in the by-angles *a* and *b*, I firſt turn the Index to view that at *a*, and draw a dry line from ⊙ 2 towards it; then I do the like towards *b*, ⊙ 3, and the tree, which laſt croſſing that drawn towards it from ⊙ 1, the interſection determines the place of the tree, which being remarkable, as ſeen from all the Stations, I mark it in my Plan; then I meaſure to *a* 412 links, and from *b* 353, and ſet them off in the dry lines drawn towards them; then I ſet off the diſtance to the bounders in the two ſtation-lines produced, *viz.* 151 in the next produced backwards, and 15 in the firſt produced forwards; then I draw the bounders from the angle where the firſt offset was made to the next,

and

and ſo on round by *a*, *b*, thro' the 151 to the next angle; then taking up my Table, I fix again the object as before, and meaſure on to ⊙ 3, which I ſet off 564 links, and the offset to the angle in the bounder 27, and then I draw the bounder from it thro' the 15 to the angle at meeting that laſt drawn.

Now taking out the object, I plant my Table to have ⊙ 3 over the hole, when placed parallel to what it was at the former Stations, and ſcrew'd faſt; then I turn the Index to make the ruler-edge touch the place of the tree and ⊙ 3 in my Plan, and finding the hair cuts the tree as it ought, I turn the Index to view ⊙ 4, and draw a dry line towards it; then taking up the Table, I fix the object as before, and meaſure on to ⊙ 4, which I ſet off 471 links, and the offset 23, and draw the bounder from the laſt angle thro' it to the next; then I meaſure on in the Station-line produced to the next bounder 207 links, and the diſtance of ⊙ 4 from the neareſt place in the ſame bounder 173, both which I ſet off, and draw the bounder from this laſt thro' the 207 to the angle.

Now taking out the object, I plant my Table to have ⊙ 4 over the hole, when ſcrew'd faſt in the ſame paralleliſm as at the other Stations; then after viewing again the tree, I turn the Index to view ⊙ 5, and draw a dry line towards it; then taking up my Table, I fix the object as before, and meaſuring on towards ⊙ 5, I find at 125 the neareſt place of

of the bounder is diſtant 121, which I ſet off bearing forwards, as the *Figure* ſhews; and at 388 the perpendicular offset is 9, and at 712 it is 12, both which I ſet off in my Plan; then I meaſure on to ⊙ 5, and ſet it off at 912 links.

Now taking out the object, I plant my Table to have ⊙ 5 over the hole, when ſcrew'd faſt in the ſame paralleliſm as before; then I ſet up objects in the by-angles *c* and *d*, and after viewing the tree, I turn the Index to view the objects at *c*, *d*, and ⊙ 6, and draw a dry line towards each; then I meaſure to *c* 159, and from *d* 245, both which I ſet off in my Plan, and alſo the diſtance to the bounder in the next ſtation-line produced backward 95; and now I make up the bounders round by the ſeveral offsets to the angles *c* and *d*; then taking up my Table, I fix the object as before, and meaſuring towards ⊙ 6, find at 162 the offset is 32, which I ſet off; then I meaſure on to ⊙ 6, and ſet it off at 708, and the offset from it to the bounder 36 links.

Now finding the dry line drawn from ⊙ 1 to interſect the point-hole here made for ⊙ 6, I do not plant my Table at ⊙ 6, but begin meaſuring from it towards ⊙ 1, and finding at right angles to the line at ⊙ 6, the offset to the angle is 42, I firſt ſet that off in my Plan; then meaſuring to ⊙ 1, I find it 582, which, meaſuring the ſame by the Scale in my Plan, proves the truth of the work; the

offset is here alſo 42, which I ſet off, and draw the bounders from *d* round by the ſeveral offsets thro' this laſt to the angle; then I meaſure on in the ſtation-line produced to the next bounder 88 links, and ſet that off alſo, and draw the bounder from the angle at the firſt offset taken thro' it to the angle at meeting the laſt bounder; and then if a Meridian-line be drawn, as in the former, the rough Plan is compleated.

But if ⊙ 6 had not met in the interſection, or it's diſtance from ⊙ 1 been too much, or too little, I ſhould very likely have all my work, except the offsets, to meaſure and plot over again; which would much vex me, eſpecially if I am ſtraiten'd for time, and can't do it the ſame day, but muſt come again the next, tho' it ſhould be a mile or two, on purpoſe for it.

The Plain-Table *Surveyors*, when they find their work not to cloſe right, do often cloſe it wrong, not only to ſave time and labour, but the acknowledging an error to their Aſſiſtants, which they are not ſure they can amend, becauſe in many caſes it is not in their power, and may be more often the fault of the Inſtrument than the *Surveyor*; for in uneven land, where the Table can't at all the Stations be ſet horizontal, or in any other one Plane, it is impoſſible the work ſhould be true in all parts: but to prevent great errors, I would (at every ⊙ after the ſecond) view, where-ever I can, the object at ſome former ⊙, beſides that

that the Table was laſt planted at; becauſe if the edge of the Index-ruler don't quite touch, or but very little covers that ⊙ in my Plan, whilſt it touches the ⊙ I am at, I may amend the error before it is more increaſed, and if it much varies, I may examine it by planting again the Table at the former Station or Stations.

If a Field is hilly, that I can't, without increaſing the number of Stations, ſee more than one object backward, and another forward, and there is nothing fit within the Field, as I ſuppoſed the tree in *Fig.* L, then I would ſet up an object on purpoſe to be view'd from all my Stations, if poſſible, for ſuch a rectifier.

The lengthening and ſhortening of the paper, as the weather is moiſter or drier, often cauſes no ſmall error in plotting on the Plain-Table; for between a dewy morning, and the Sun ſhining hot at noon-day, there is great difference, and care ſhould be taken to allow for it; but that can't be done in large Surveys, and ſo ought not to be expected: indeed thoſe working by the degrees, without having their Plan on it, are not liable to this error, tho' they are to the former; but both ways are liable to another error, which is, that the ſtation-lines drawn, or the degrees taken, are not in the line between the objects, nor parallel thereto; neither will this error be ſmall in ſhort diſtances, and may be great, if each ⊙ on the Plan, or the center uſed with the

degrees, is not exactly over the Station-holes; but to be moſt exact, it is the line of their Sights, that ſhould be directly over the hole.

Mr. *Siſſon* has made ſuch improvements to his Plain-Tables, which each by a conical Ferril fix on the ſame ſtaves as his Theodolite, that the above errors, except that of the paper, are thereby remedied; for the line of the Sights in viewing is always over the center of the Table, which is as readily ſet perpendicular over the hole, as the center of his Theodolite, and the ſtation-lines drawn parallel to thoſe meaſured on the land; and the Table is ſet horizontal with a Spirit-Level by the ſame four ſcrews that adjuſt the Theodolite; therefore Some chuſe to have both Inſtruments, that they may uſe either, as they ſhall think moſt convenient.

Let *Fig.* L now be a Wood, that I muſt meaſure and plot on the outſide; if on my coming round to my firſt ⊙, the lines meet as they ought, the Plan will be as truly made, as if done on the inſide; but here having no rectifier of my work as I go on, I muſt truſt to the cloſing of the laſt meaſured line; and if that does not truly cloſe with the firſt, I muſt go over the work again, and without a better Inſtrument than the common Plain-Tables, I can't be ſure of not making ſuch an error in this caſe.

Suppoſe my Table planted at ⊙ 1 on the outſide, with paper fixt on it, and objects ſet up at all the other Stations on the outſide, and

dry

dry lines drawn from ⊙ 1 on the paper towards ⊙ 6 and ⊙ 2; theſe done, I take up my Table, and ſet up an object at ⊙ 1; then meaſuring from it towards ⊙ 2, I find at 20 the offset to the firſt angle is 38, then at 280 the offset to the next angle is 26 links, both of which I ſet off in my Plan; then at 394 the perpendicular offset to the next angle is 206; then at 698 the diſtance of the ſame angle is 366 bearing backward, as may be ſeen in the *Figure*, that by the interſection of theſe two offset-lines the angle may be more truly plotted; then I meaſure the diſtance from this angle to the next 323, and from that to 698 place in the ſtation-line 280, which is the perpendicular offset; then by the interſection of theſe, that angle will be well plotted; then at 776 the offset to angle *a* is 48, and at 1012 the offset to *b* is 22, both which I ſet off in my Plan, and at 1306 I make ⊙ 2; and now I draw the bounders from the firſt offset to the next, *&c.* to the angle *b:* As there is no difficulty in taking the offsets from the other ſtation-lines, I ſhall not proceed farther in plotting it on the outſide; for a ſight of the *Figure* is ſufficient.

Some *Surveyors* would plant their Table at ſome place between 394 and 698 in the firſt ſtation-line, and take the two angles (which I here plot by the interſection of lines) as the by-angles *a* and *b* were taken at ⊙ 2 within the Field; but if the bounder ſhould not be a ſtreight line from one angle to the other, then

their

their diſtance ſhould be meaſured, and offsets taken to the ſeveral bends in it.

Sect. 3. *Shewing how to meaſure an inacceſſible diſtance, and alſo to plot on the Plain-Table a Field at two Stations, where all the angles may be ſeen at each, either within or without the Field, by meaſuring on the land only the diſtance between the two Stations.*

I plot an inacceſſible diſtance in the ſame manner as the Tree in *Fig.* L; for if I could come no nearer to it than the ſtation-line, yet I might with my Scale meaſure it's diſtance from ⊙ 1, or ⊙ 2, or any part of the line between them in my Plan, the ſame as if I meaſured it with my Chain on the land; but I obſerve to make the Stations at ſuch diſtance from one another, that the lines drawn towards the Tree may interſect each other as near as poſſible to right angles.

Let *Fig.* M be a Field to be plotted as above.

Having ſet up objects at all the ſix angles, and at ⊙ 2, and planted my Table at ⊙ 1 with paper fixt on it, and made ⊙ 1, I lay the Index-ruler cloſe thereto, whilſt viewing all the objects, and draw dry lines from it towards each; then I make a hole in the ground exactly under ⊙ 1 on the Table, and ſet up an object in it, and meaſure from it to ⊙ 2, and ſet off the diſtance in my Plan; now I plant the Table at ⊙ 2, and ſcrew it faſt in the ſame paral-

paralleliſm as at ⊙ 1, by the Index-ruler touching both Stations in my Plan, whilſt the hair cuts the object at ⊙ 1; then I turn the Index to view all the other objects, and draw dry lines towards each; then the points where theſe interſect the former, are the ſeveral angles in my Plan, and black lines drawn from each to the next, will be the bounders of the Field.

This method requires the being very curious in drawing the dry lines, and to contrive the Stations ſo, that each of theſe lines may meet thoſe drawn from the other ⊙, as near as poſſible to right angles; becauſe whatever is thus plotted by the interſection of lines, if they interſect with very acute or obtuſe angles, the leaſt variation in drawing either of the lines, will alter the point of meeting conſiderably.

By this method ſuch a Field as *Fig.* M may be plotted without meaſuring one line in it, or near it; if the Plain-Table can be planted at two Stations on high ground without the Field, from whence objects in all the angles can be ſeen at each; for it is only conceiving each angle to be an inacceſſible diſtance, and ſo the whole Field will be plotted by meaſuring only the diſtance between the two Stations.

Alſo the Perſpective of a *Town*, *City*, &c. may be taken in this manner, by obſerving at two Stations the Spires, and other remarkable things, that can be ſeen at them; for

when theſe are determined by the interſections, the leſs remarkable may be done by ſight at either ⊙, or in any part of the ſtation-line.

If a third Station is made in any of theſe caſes, and obſervations made of the ſame things, by interſections nearer to right angles with either of the former, and if theſe laſt meet in the ſame points, it will prove the truth of the work; and if otherwiſe, ſome corrections may be made by it, or the former again repeated, whilſt near thoſe Stations.

CHAP.

CHAP. III.

Shewing how to ſurvey a Field or other piece of land by the Theodolite, Circumferentor, or degrees on the Plain-Table, and to plot the ſame.

Sect. 1. *That the Theodolite as improved by Mr.* Siſſon *is the beſt Inſtrument for plotting large Tracts of land.*

THE Plain-Table may ſtill be, if conſiderately managed, very uſeful in planning the Ground-Plat of *Buildings*, Gardens, or a few ſmall parcels of land nearly on a level; but it is unfit in general for the *Practical Surveyor*, who ought to have an Inſtrument whereby to plot large Tracts of land as well as ſmall, of hilly as well as on a level; for doing which there is none comparable to this Theodolite; for all the others are only Approachers towards this, as this is to the truth, and are included in it; however, not to be defective, I muſt ſhew the uſes of thoſe others, in doing that which is much better done by this contrived by the ingenious Mr. *Siſſon*,

who has made ſuch improvements therein, that, if care be uſed, no more are wanted for the taking of Angles in the field; the thing wanted was to plot them as exact; but that I did not hope for; therefore I was ſatisfied with the Approach I had made towards it: but Mr. *Siſſon* has lately contrived a new Protractor, and Scale of equal parts, with ſuch apparatus to them, that the ſtation-lines of a large Survey (if they could be given true) might be as truly plotted, as their angles and meaſured lengths can be taken on the land.

Here I can't but reflect on the inconſideration of many Gentlemen, who are much pleaſed with very incorrect Surveys of their Eſtates, who ſeeing their Maps picture-like drawn, and the writing in them neat, from thence infer that they are Plans, tho' they can't be juſtly called ſuch; they may indeed be better than Eye-Draughts in the dimenſions, and yet worſe in the ſhape of the bounders, as ſuch Gentlemen who will a little examine their Maps on the land (where the bounders are curves of many ſhapes, whether hedges or brooks) will ſoon find them far from truth; and as this is the caſe with almoſt all that I have had the opportunity of examining, ſo I muſt believe the Meaſures may be far from truth alſo; for I have found them ſo in very many, in ſome ſo far, that the Tenants by their *Mowing*, *Plowing*, &c. have found it alſo, and ſome have told me, it is not for them to tell their Landlords, where the quantities are given too little;

little; and the modeſt *Surveyors* (who were ſenſible of their own failings) have generally taken heed not to reckon them too much; whereas if we could plot our work true, the quantities might be given very near it: now by taking our Angles ſo truly with this Theodolite, we can, with ſkill, care, and induſtry, come aſſuredly ſo near truth in plotting, as not to be detected in an error by any means: but if Gentlemen will not pay anſwerable to the care and induſtry requiſite, they may ſuffer very conſiderable damage by either new or old erroneous Surveys.

Sect. 2. *Shewing how to ſurvey a Field, or other piece of land, by a common Theodolite, Semi-Circle, or the degrees on the Plain-Table.*

Let *Fig.* L be the Field to be ſurvey'd.

Firſt, I ſet up objects as before, ſo as not to to have more ſtations than needful, and the ſtation-lines as near the bounders as I can, either within or without the Field.

Suppoſe my Theodolite graved to 360 degrees, with *Nonius*'s diviſions for the minutes, and having a plumb line under it's center to ſet it directly over the object-holes, and planted at ⊙ 1 within the Field; then I bring the Index to 360, and turn the whole to make the hair in the ſights cut the object at ⊙ 6, and ſcrew it faſt; then I turn the Index, that the ſame hair may cut the object at ⊙ 2, and

write down in my field-book the degree and minute ſhewn by the Index, *viz.* 259° : 42′, with the Bearing by the Needle; then taking up my Theodolite, I fix an object exactly over the hole, and meaſure from it to ⊙ 2, and beyond to the interſection of the bounder in the line produced, writing down my offsets as I meaſure on, and int. for the interſection; I place every particular length of the ſtation-line from whence an offset is taken under the Angle, and the quantity for each offset to the right hand or the left, as it is in the field, when I ſtand on the line looking back to the object I meaſure from, that being moſt natural in writing them down, and making the ſhapes of the bends in the bounders as I go on; but where an offset is not taken perpendicular to the ſtation-line, I annex a ſhort black line to ſhew it's deviation.

Being come to ⊙ 2 I take out the object, and plant my Theodolite exactly over the hole, and bringing the Index to 360, I turn the whole to view ⊙ 1, and ſcrew it faſt; then I turn the Index to view objects at *a*, *b*, and ⊙ 3, writing down the degree and minute ſhewn by the Index for each, and then I meaſure their diſtances, as before in plotting on the Plain-Table, whither I muſt refer the Reader, if he does not underſtand the ſame quantities in the following Form.

⊙ 1

⊙1 . . . 259° : 42′, and 104° by the Needle
218 157
375 6
698 6
1041 to 2 ⊙ . . . 151—
1056 int.

by angles { 36 : 5 . . . . . 412 to *a*
70 : 40 . . . . . 353 to *b*

⊙2 . . . 290 : 28
564 to 3 ⊙ . . . 27

⊙3 . . . 127 : 4
471 to 4 ⊙ . . . 23
678 int.

⊙4 . . . 285 : 11
0 . . . . . 173—
125 . . . . . 121—
388 9
712 12
912 to 5 ⊙ . . . . 95—

by angles { 119 : 30 . . . . . 159 to *c*
190 : 40 . . . . . 245 to *d*

⊙5 . . . 259 : 28
162 32
708 to 6 ⊙ . . . 36

⊙6 . . . 218 : 7
0 42
582 to 1 ⊙ . . . 42
670 int.

Note,

Note, If the Survey is made by a Semi-Circle number'd firſt to 180, and then again on to 360, or by the degrees on the Plain-Table, the Angles would be the ſame, if taken as true, and there would be no difference in writing down the Obſervations.

Sect. 3. *Shewing how to plot the foregoing Obſervations.*

As the Angles were meaſured on the land with a Theodolite, they are to be plotted with a Protractor number'd like the Theodolite, that on the paper it may repreſent the Theodolite on the land; and to this end a whole circle is better than a ſemi-circle, tho' the latter (number'd firſt to 180, and then again on to 360) hath been moſtly uſed; but if the *Practical Surveyor* would allow himſelf to ſpend ſo much time in this part of his work, which requires his utmoſt diligence to be exact, as in ſetting off his Angles, to ſet them off on both ſides, *viz.* them and their oppoſites, then the whole circle is equal to a ſemi-circle of double the radius; for the larger the Protractor the more truly may the Angles be ſet off; but then the whole circle muſt be divided into half degrees, and doubly number'd, that is, it muſt be number'd from both ends of the diameter at every ten degrees round to 360.

Having my Protractor, Scale, Paper, *&c.* ready, I firſt conſider where to place ⊙ 1, that the whole may come within my paper, if poſ-

ſible,

ſible, without paſting more to it; then making ⊙ 1, I draw at diſcretion a dry line from it for ⊙ 2, and ſet off therein with my Scale 1041, the length of the firſt line, and there I make ⊙ 2; then applying the center of my Protractor to ⊙ 2, with it's diameter directly over the dry line already drawn, and extended both ways more than the radius, I ſet off with my protracting pin the Angles taken at ⊙ 2, *viz.* 36°: 5′, 70°: 40′, and 290°: 28′, and drawing dry lines from ⊙ 2 thro' each, I ſet off in the laſt 564 for ⊙ 3; then making ⊙ 3, I apply the center of my Protractor to it with the diameter over this laſt dry line, and ſet off the Angle 127°: 4′, and draw a dry line thro' it, and ſet off therein 471 for ⊙ 4; and ſo I go on ſucceſſively with all my ſtation-lines, till I come round to ⊙ 1, where I began, and if it meets exactly in the point, I may be ſure my ſtation-lines are well plotted: the manner of plotting the offsets from the ſtation-lines for the bounders, is as before directed on the Plain-Table; alſo the Angles of interſection for the tree, or any other inacceſſible diſtance may be taken, and plotted like the Angles of any other object, and therefore need not be repeated.

Note, Planting the Theodolite at ⊙ 2, ⊙ 3, ⊙ 4, and ⊙ 5, takes all the Angles needed in plotting this ſingle Field; but if a large circuit is taken in at once, it would be neceſſary to take the Angle at every ⊙.

Sect.

Sect. 4. *Shewing the method of proving the Angles, when all are taken.*

I add the quantities taken for every Angle (whether over or under 180 degrees) into one ſum; then I multiply 180 by a number greater or leſs by two than the number of Angles or Stations, and if this product be equal to the ſum of the quantities taken, it is a proof that they are well taken.

Let the number of Angles be ſix, as in the foregoing Example, and the ſum of the quantities 1440; then 180 multiplied by 8 (the number of Angles increaſed by two) being alſo 1440, proves thoſe Angles well taken; but if the ſaid quantities had been taken inward inſtead of thoſe taken outward, then their ſum would have been but 720 equal to 4 times 180.

Sect. 5. *Concerning the Circumferentor.*

The Circumferentor is much like a common Theodolite without it's Limb; for it has a compaſs-box ſcrew'd to a braſs plate much like the Index; and this Index has alſo plain ſights, and turns on a cylinder, which is moveable by a ball and ſocket, and the whole ſupported by a three-legg'd Staff.

The compaſs-box is divided into 360 degrees, number'd by tens to 360, and alſo to four nineties from the North and South points, and at the North point is a flower-de-luce.

In

In ſurveying *Commons*, *Roads*, or *Waſte-Lands*, where only the ſhape of the bounders, and the length of the lines are required nearly, but not with accuracy either in them or the quantity, the Circumferentor may do well enough for the angles (with a meaſuring Wheel for the lines, whoſe Indexes may be made to ſhew chains and links as well as miles and furlongs) but it is by no means a fit Inſtrument for taking a Plan, where exactneſs is required; becauſe we can't be certain of it's giving any particular angle ſo near as two degrees; for in ſurveying large quantities with my Theodolite, I have frequently found my Needle varying more than five degrees, and therefore I reject ſuch dependance on it; however, in the above caſe I will ſuppoſe it to be uſed, by reaſon great diſpatch of buſineſs may be made with it; for if we can ſee a tree, or any object held up at a great height, and take it's Bearing, and meaſure on to it, we never heed to look back to any object left at the ⊙ we meaſured from; tho' if we did, we might be ſenſible of the Needle's erring, but we could not rectify it; indeed we might take the middle between, but that may not mend the matter; therefore the *Practical Surveyor* will uſe his Theodolite in the above caſe, as well as that which requires more exactneſs, and will depend on the Needle in thoſe angles only, where it will be of ſervice to his having the longer ſtation-lines; and ſo take every opportunity that offers of looking backwards and

forwards, thereby taking thoſe angles certain on the Limb; and then in plotting his ſtation-lines, he will alter the angles of thoſe only that depended on the Needle, in order to make his work cloſe; and thus with care he may come ſo near, as not to vary widely from truth; for it may be much nearer in moſt places than large Surveys are commonly done with the Plain-Table.

With the Theodolite we commonly take the Angle made by the meeting of two lines at the center of the Inſtrument; but with the Circumferentor we take the Angle made by the Needle with every ſtation-line, and the diviſions in the compaſs-box ſhew what it is at each ⊙; ſo that if the Needle was in every place parallel, we could do very well with this Inſtrument; but tho' it is not, yet I ſhall ſhew the uſe of it.

Sect. 6. *Shewing how to ſurvey a Field, or other piece of land, with the Circumferentor.*

Let *Fig.* L be the Field to be ſurvey'd.

My objects being all ſet up as before, I begin with writing down in my field-book 1 ⊙ line, leaving ſpace for putting in the Angle or Bearing, till after I have planted my Circumferentor at ⊙ 2, and view'd the object at ⊙ 1; then I meaſure from ⊙ 1 to ⊙ 2, and write down the parts of my ſtation-lines, and the offsets againſt them, as in ſurveying with the Theodolite.

Being

Being come to ⊙ 2, I plant there my Circumferentor, then I firſt view the object left at ⊙ 1, and fill up the ſpace left for the Bearing of the firſt ſtation-line with the degree the South end of the Needle points to; becauſe if I had view'd ⊙ 2 from ⊙ 1, the North end of the Needle would have pointed to the ſame; then I view the objects at the by-angles *a* and *b*, and alſo at ⊙ 3, writing down the degree that the North end of the Needle points to at each; then after meaſuring to each, and from ⊙ 3 to ⊙ 4, I plant my Circumferentor at ⊙ 4, and firſt viewing the object at ⊙ 3, I fill up the ſpace left for the Bearing of the third ſtation-line with the degree the South end of the Needle points to, as I did for the firſt, and then I view ⊙ 5, and write down the degree the North end points to, then after meaſuring to ⊙ 5, I plant there my Circumferentor, becauſe of the by-angles to be taken, and firſt viewing back to ⊙ 4, I look if the South end of the Needle now points to the ſame degree, and if it does not, I note the difference, that a correction (if needful) may thereby be made in plotting; then I view the objects at the by-angles *c* and *d*, and alſo at ⊙ 6, and write down the degree the North end of the Needle points to for each; then after meaſuring to each, and from ⊙ 6 to ⊙ 1, I plant my Circumferentor at ⊙ 1, (tho' if the Bearings of the firſt five ſtation-lines are truly taken, there would be no need of the ſixth) and firſt viewing back to ⊙ 6, I write down the degree the South end

of the Needle points to, and then I view to ⊙ 2, and see if the North end of the Needle points to the same degree as was at first written down, and if it differs, I note it; but if the Bearings agree, the Work will be in the following Form.

1 ⊙ line . .	104°	
	218	157
	375	6
	698	6
	1041 to 2 ⊙ . . .	151
	1056 int.	
by-angles	320	412
	354½	353
2 ⊙ line . .	214½	
	564 to 3 ⊙ . . .	27
3 ⊙ line . .	161½	
	471 to 4 ⊙ . . .	23
	678 int.	
4 ⊙ line . .	266¾	
	0	173
	125	121
	388	9
	712	12
	912 to 5 ⊙ . . .	95
by-angles	206¼	159
	277⅓	245

5 ⊙ line . . 346° ¼
162 32
708 to 6 ⊖ 36

6 ⊙ line . . 24 ¼
0 42
582 to 1 ⊖ 42
670 int.

Note, I have ſuppoſed the flower-de-luce in the compaſs-box always from me in viewing, that, if with a Teleſcope, there might be no difference.

Sect. 7. *Shewing how to plot the foregoing Obſervations.*

The common Method hath been firſt to draw ſeveral parallel lines quite thro' the intended Plan, at ſuch diſtance from each other as not to exceed the radius of the Protractor, which lines were to repreſent ſo many magnetick Meridians, each markt with *N* and *S*, for *North* and *South*; the Protractor was a ſemi-circle divided into 180 degrees, and firſt number'd by tens to 180, and then again to 360, both the contrary way to the compaſs-box; if the Bearing of a ſtation-line was leſs than 180 degrees, the center was laid to the ⊙, with the diameter parallel to the Meridians, and the beginning of the numbers towards *N*; but if more than 180, the beginning

ning was laid towards *S*; and ſo the Bearing of every ſtation-line was ſet off at the preceding ⊙.

But there is another Method much more exact and expeditious, which is, by fixing a circular Protractor (number'd alſo contrary to the compaſs-box) down on the paper, and ſetting off the Bearings of all the ſtation lines, tho' never ſo many, at that once fixing it down; then by a parallel Ruler they are each readily transferr'd to it's proper ⊙, and by this means the dry lines drawn from each ⊙ for the ſucceeding ſtation-line will be more true in their Bearings, by being ſet off at once fixing the Protractor.

But I muſt ſtill add, that he who will depend on the Needle in ſurveying Land, ſhould not take in a large compaſs at one circuit; for altho' he may keep a continued chain of work throughout, and uſe this Method of ſetting off the Bearings of all his lines at once fixing down his Protractor, yet he muſt not fail cloſing his work in ſmall parcels; and then if his errors be many, yet each will be but ſmall, provided no error is made in the meaſure of the lines, of which there is no ſmall danger, tho' great care be uſed; becauſe the uncertainty of their Poſitions will make their points of meeting uncertain alſo.

Sect.

Sect. 8. *Shewing how to ſurvey a Field, or other piece of land, with Mr.* Siſſon's *Theodolite number'd to* 360, *and having the compaſs-box fixt on the Index-plate, and number'd the ſame, with a Teleſcope,* &c. *as deſcribed by me in the* 36*th Article of Mr.* Laurence's Duty of a Steward.

Let *Fig.* L be the Field to be ſurvey'd.

My objects being all ſet up, I write down in my field-book 1 ⊙ line, leaving ſpace for the Angle; then I meaſure with my Chain from ⊙ 1 to ⊙ 2, and write down the parts of my ſtation-lines and the offsets, as in ſurveying with a common Theodolite.

Being come to ⊙ 2, I plant my Theodolite exactly over the hole by a plumb-line hanging under it's center, and having ſet it horizontal, I bring the chief Index to 360 on the Limb, and turn the whole to bring 360 in the compaſs-box to the North end of the Needle; then I move the Indexes to make the vertical hair in the Teleſcope cut the objects at ⊙ 1, *a*, *b*, and ⊙ 3, writing down the degree and decimal the chief Index ſhews for each, which will be the ſame with the Needle, and as the Teleſcope is directed to ⊙ 3, I ſcrew faſt the Index to the Limb; then taking up my Theodolite, I ſend it to ⊙ 3, where (after ſetting up again the object at ⊙ 2, and meaſuring from it to *a*, *b*, and ⊙ 3) I plant it exactly over the hole, and having ſet it horizontal, I turn the

Limb

Limb till the vertical hair in the Teleſcope cuts the object at ⊙ 2; then looſening the Index-ſcrew, I turn the Indexes till the ſame hair cuts the object at ⊙ 4, and write down the degree and decimal ſhewn on the Limb, which is the ſame that the South end of the Needle now points to; then ſeeing alſo the object at ⊙ 5, I fix the Index as the hair cuts that object; now meaſuring to ⊙ 4, and from ⊙ 4 to ⊙ 5, I plant my Theodolite at ⊙ 5, and turn the Limb about till the hair cuts the object at ⊙ 3; then looſening the Index-ſcrew, I turn the Indexes till the hair cuts the objects at ⊙ 4, *c*, *d*, and ⊙ 6, writing down the degree and decimal ſhewn by the Index for each, which will now be the ſame by the North end of the Needle; then ſcrewing faſt the Index, I ſend my Theodolite to ⊙ 6, where (after meaſuring to *c*, *d*, and ⊙ 6) I plant it, and turn the Limb about till the hair cuts the object at ⊙ 5; then looſening the Index-ſcrew, I turn the Indexes till the hair cuts the object at ⊙ 1, and write down the degree and decimal ſhewn on the Limb, which is the ſame that the South end of the Needle now points to; then meaſuring to ⊙ 1, and beyond in this, as well as the firſt and third ſtation-lines, to interſect the bounders, finiſhes the work in the Field, which may be in the following Form.

1 ⊙ line .. 284°, 02
218 157
375 6
698 6
1041 to 2 ⊙ 151
1056 int.

by-angles { 320, 1 412
354, 68 353

2 ⊙ line .. 214, 48
564 to 3 ⊙ 127

3 ⊙ line . . 341, 55
471 to 4 ⊙ 123
678 int.

4 ⊙ line . . 86, 73
0 173
125 121
388 9
712 12
912 to 5 ⊙ 95

by-angles { 206, 23 159
277, 4 245

5 ⊙ line . . 346, 2
162 32
708 to 6 ⊙ 36

6 ⊙ line . . 204, 32
0 42
582 to 1 ⊙ 42
670 int.

Sect. 9. *Shewing how to plot the foregoing Obſervations by my Method, as mention'd in the ſaid Article.*

Having paper ready, I pin down a large circular Protractor thereon, divided into half degrees, and number'd from both ends of the diameter at every tenth degree quite round to 360, the ſame way as the Theodolite, and thereby I ſet off all my Angles (tho' never ſo many) on both ſides it's diameter at this once fixing it down, according to the quantities given on the Limb of the Theodolite; and they are the more truly ſet off by the Protractor being fixt but once for all, and by ſetting them off on both ſides the diameter, that I have with the center three points to apply my parallel Ruler to, for transferring theſe Angles thus ſet off to the place of every ⊙, to draw the ſucceeding ſtation-line.

The Angles being all ſet off, I make ⊙ 1 where I judge moſt convenient; then I apply the inner or outer edge of my parallel Ruler next the light, to the points made for the Angle of 1 ⊙ line, and moving it parallel to have either edge touch ⊙ 1, I draw a dry line from ⊙ 1 for ⊙ 2, and at the diſtance of 1041 links I ſet off therein ⊙ 2; then I apply either edge to the points made for the Angle of 2 ⊙ line, and moving it parallel to ⊙ 2, I draw from it a dry line, and ſet off therein ⊙ 3; then I do the like for all the ſtation-lines, till

I come round again to ⊙ 1, where I began; and if no error is committed, it will meet in the very point.

The ſtation-lines being plotted, I ſet off the by-angles *a* and *b* from ⊙ 2, and *c* and *d* from ⊙ 5; then I plot the offsets from the ſtation-lines, and draw the bounders, as before on the Plain-Table.

Sect. 10. *Containing a deſcription of Mr.* Siſſon's *lateſt improved Theodolite.*

The three Staves by braſs ferrils at top ſcrew into bell-metal joints, that are moveable between braſs pillars fixt in a ſtrong braſs plate, in which round the center is fixt a ſocket with a ball moveable in it, and upon which the four ſcrews preſs that ſet the Limb horizontal; next above is another ſuch plate, thro' which the ſaid ſcrews paſs, and on which round the center is fixt a fruſtum of a Cone of bell-metal, whoſe axis (being connected with the center of the ball) is always perpendicular to the Limb, by means of a conical braſs ferril fitted to it, whereon is fixt the Compaſs-Box, and on it the Limb, which is a ſtrong bell-metal ring, whereon are moveable three braſs Indexes, in whoſe plate are fixt four braſs pillars, that, joining at top, hold the center-pin of the bell-metal Double-Sextant, whoſe double Index is fixt on the center of the ſame plate; within the Double-Sextant is fixt the Spirit-

Level, and over it the Teleſcope. See the *Figure* fronting the Title-page.

The Compaſs-Box is graved with two diamonds for *North* and *South*, and with 20 degrees on both ſides of each, that the Needle may be ſet to the Variation, and it's error alſo known.

The Limb has two flower-de-luces againſt the diamonds in the Box, inſtead of 180 each, and is curiouſly divided into whole degrees, and number'd to the left hand at every ten to twice 180, having three Indexes diſtant 120, (with *Nonius*'s diviſions on each for the decimals of a degree) that are moved by a pinion fixt below one of them without moving the Limb, and in another is a ſcrew and ſpring under, to fix it to any part of the Limb: it has alſo diviſions number'd for taking the quarter Girt in inches of round *Timber* at the middle height, when ſtanding ten feet horizontally diſtant from it's center, which at 20 muſt be doubled, and at 30 trebled, to which a ſhorter Index is uſed, having *Nonius*'s diviſions for the decimals of an inch; but an abatement muſt be made for the bark, if not taken off.

The Double-Sextant is divided on one ſide from under it's center (when the Spirit-Tube and Teleſcope are level) to above 60 degrees each way, and number'd at 10, 20, *&c.* and the double Index (thro' which it is moveable) ſhews on the ſame ſide the degree and decimal of any Altitude or Depreſſion to that extent by *Nonius*'s diviſions; on the other ſide are diviſions

ſions number'd for taking the upright height of *Timber*, *&c.* in feet, when diſtant ten feet, which at 20 muſt be doubled, and at 30 trebled; and alſo the quantities for reducing hypothenuſal Lines to horizontal: it is moveable by a pinion fixt in the double Index.

The Teleſcope is a little ſhorter than the diameter of the Limb, that a fall may not hurt it; yet it will magnify as much, and ſhew a diſtant object as perfect, as moſt of treble it's length; in it's focus are very fine croſs-wires, whoſe interſection is in the Plane of the Double-Sextant, and this was a whole Circle, and turn'd in a Lathe to a true Plane, and is fixt at right angles to the Limb; ſo that whenever the Limb is ſet horizontal (which is readily done by making the Spirit-Tube level over two ſcrews, and the like over the other two) the Double-Sextant and Teleſcope are moveable in a vertical Plane, and then every Angle taken on the Limb (tho' the Teleſcope be never ſo much elevated or depreſt) will be an Angle in the Plane of the Horizon, and this is abſolutely neceſſary in plotting a horizontal Plan: ſuppoſe an Angle taken on a hill-ſide by a Theodolite, having a Teleſcope (moveable at right angles to the Limb) depreſt ten degrees both in viewing backward and forward, and that the Limb is two degrees from the horizontal Plane nearer to the hill-ſide, which ſuppoſe much ſteeper, and that theſe two lines (when reduced to the Horizon) is one, or 180°; I ſay, the Theodolite will give it but 179°: 18′: 18″,

and

and the next ☉, if diſtant ten chains, diſplaced above 12 links, and if longer, proportionally more: now if the Theodolite has no Teleſcope, and an obſervation is alſo made down the ſteeper declivity at right angles to theſe lines, the *Surveyor* (who is not aware of this error) may make the Limb deviate more than ten degrees towards this declivity, which, if juſt ten degrees, then the two lines (that reduced to the Horizon is one, or 180°) will be made an Angle leſs than 176° : 29′ : 33″, and the next ☉, if diſtant ten chains, diſplaced above 61 links. See the Calculation.

As Rad. to Sine 10° . . . = Log. 9.2396702
So Tang. 10 . . . . = Log. 9.2463188

To the Tang. 1 : 45′ : 13″ $\frac{5}{8}$ = Log. 8.4859890

Which being doubled (as the Angle is equally affected by the back obſervation as the forward) and ſubtracted from 180° leaves ſomewhat leſs than 176° : 29′ : 33″,

As Rad. to Sine 1 : 45 : 13 $\frac{5}{8}$ = Log. 8.4857856
So is 1000 links . . . . . = Log. 3.0000000

To 30,6045 links . . . . = Log. 1.4857856

Which being alſo doubled, as being for half an iſoſceles Triangle, makes 61,209 links.

Sect.

Sect. 11. *Shewing how to ſurvey any piece of land by the ſaid Theodolite.*

Let *Fig.* L be a Field to be ſurvey'd.

My objects being all ſet upright in the holes made for every ⊙, I write down 1 ⊙ line, leaving ſpace for the Angle; then I meaſure with my Chain from ⊙ 1 to ⊙ 2, and write down the parts of my ſtation-lines and the offsets, as in ſurveying with a common Theodolite.

Being come to ⊙ 2, I plant my Theodolite exactly over the hole by a plumb-line hanging under it's center, and making the Limb horizontal, I turn it about to have the Needle in the line between the two diamonds, or rather to the Variation, which at *London* is now $15^{\circ}\frac{1}{2}$ Weſt; then by the pinion I turn the Indexes till the upright wire in the Teleſcope cuts the object at ⊙ 1, and fill up the ſpace left with the degree and decimal ſhewn by the chief Index on the Limb, *viz.* 88°, 52; but as ⊙ 1 is on the Weſt ſide of the Meridian, ſo if I had planted my Theodolite at ⊙ 1, then ⊙ 2 would have been the very ſame on the Eaſt ſide; therefore I write it 88°, 52 Eaſt; now by the pinion I turn the Indexes to make the ſame wire cut the objects at *a*, *b*, and ⊙ 3, writing down the degree and decimal the ſame Index ſhews for each, and adjoining on which ſide of the Meridian each is, and as it cuts that at ⊙ 3, I ſcrew faſt the Index to the Limb; then

then taking up my Theodolite, I ſend it to ⊙ 3, where (after meaſuring to *a*, *b*, and ⊙ 3) I plant it over the hole, and making the Limb horizontal, I turn it, to have the ſame wire in the Teleſcope cut the object at ⊙ 2; then I looſen the Index, and by the pinion turn it about to make the wire cut the object at ♉ 4, and write down the degree and decimal ſhewn by the Index; then ſeeing the object at ♉ 5, I turn the Index to make the wire cut that alſo, and ſcrew it faſt; now meaſuring to ♉ 4, and from ♉ 4 to ♉ 5, I plant my Theodolite at ♉ 5, and making the Limb horizontal, I turn it to have the wire cut the object at ♈ 3; then I looſen the Index, and turn it to make the wire cut the object at ♉ 4, and write down the degree and decimal in the ſpace left for it againſt 4 ♉ line, but on the contrary ſide of the Meridian, as I did for 1 ♉ line; now I turn the Index to make the wire cut the objects at *c*, *d*, and ⊙ 6, writing down the degree and decimal for each; and as it cuts that at ⊙ 6, I ſcrew faſt the Index; now meaſuring to *c*, *d*, and ⊙ 6, I plant my Theodolite at ⊙ 6, and making the Limb horizontal, I turn it to have the wire cut the object at ⊙ 5; then I looſen the Index, and turn it to make the wire cut the object at ⊙ 1, and write down the degree and decimal, adjoining on which ſide of the Meridian; for the flower-de-luces on the Limb are at every ⊙ placed in the Meridian, and the Needle will ſhew the *North* from the *South*; now meaſuring to ⊙ 1, and beyond in this, as well as the firſt, and third ſtation-

ſtation-lines, to interſect the bounders, finiſhes the work in the Field, which I write down in the following Form.

1 ⊙ line . .	88°,52	East	
	218	. . . . .	157
	375	. . . . .	6
	698	. . . . .	6
	1041 to 2 ⊙	. . .	151
	1056 int.		
by-angles	124,6	West	412
	159,18	West	353
2 ⊙ line . .	18,98	West	
	564 to 3 ⊙	. . .	27
3 ⊙ line . .	146,05	East	
	471 to 4 ⊙	. . .	23
	678 int.		
4 ⊙ line . .	71,23	West	
	0	. . . . .	173
	125	. . . . .	121
	388	. . . . .	9
	712	. . . . .	12
	912 to 5 ⊙	. . . .	95
by-angles	10,73	West . . .	159
	81,9	West	245
5 ⊙ line . .	150,7	West	
	162	. . . . .	32
	708 to 6 ⊙	. . . .	36

6 ⊙ line . . 8°,82 East
0 42
582 to 1 ⊙ 42
670 int.

Sect. 12. *Shewing how to plot theſe Obſervations.*

Having paper ready, I pin down a large circular Protractor thereon, divided into degrees and halves, and number'd from each end of the diameter by tens to 180 at the other, the ſame way as my Theodolite, and thereby I ſet off (as before) all my Angles on both ſides it's diameter at this once fixing it down; ſo that here alſo I have, with the center, three points to apply my parallel Ruler to, for transferring theſe Angles thus ſet off to their proper ⊙; and by writing down Eaſt or Weſt to each Angle, I readily know which way to draw the ſtation-line from every ⊙, which, by the former method of numbering to 360, requires ſome conſideration; becauſe every planting of the Theodolite reverts the foregoing obſervation; therefore the numbering to twice 180 is much preferable in this method of plotting a Survey; the diameter of the Protractor I ſet off alſo, and draw it firſt for a true Meridian, and mark it with N and S, for North and South; then I make ⊙ 1 where moſt convenient, and applying either edge of my parallel Ruler next the light to the points made for the Angle of 1 ⊙ line, I move it parallel to have either edge touch ⊙ 1, and draw a dry line from ⊙ 1 toward the

the East side of the Meridian for ⊙ 2, and set off therein, at the distance of 1041 links, ⊙ 2; then I apply either edge to the points for 2 ⊙ line, and moving it parallel to ⊙ 2, I draw a dry line from it toward the West side, and set off therein 564 to ⊙ 3; then I apply either edge to the points for 3 ⊙ line, and moving it parallel to ⊙ 3, I draw a dry line from it toward the East side, and set off therein 471 to ⊙ 4; now I apply either edge to the points for 4 ⊙ line, and moving it parallel to ⊙ 4, I draw a dry line from it toward the West side, and set off therein 912 to ⊙ 5; now I apply either edge to the points for 5 ⊙ line, and moving it parallel to ⊙ 5, I draw a dry line from it toward the West side, and set off therein 708 to ⊙ 6; now I apply either edge to the points for 6 ⊙ line, and moving it parallel to ⊙ 6, I draw a dry line from it toward the East side, and find ⊙ 1 therein exactly at the distanee of 582 links, if I make no mistake.

The station-lines being truly plotted, I set off the by-angles *a* and *b* from ⊙ 2, and *c* and *d* from ⊙ 5; then I mark the places in each station-line from whence an offset was taken, and also where produced any intersected the bounder; then turning the Scale, and laying it to each of the former, I set off each offset, either perpendicular, or agreeable to the short black line, where one is annexed; then drawing the bounders thro' the offset points, finishes the rough Plan; but if the bounders are

curves, I make their ſhape in my field-book, and draw them accordingly.

Sect. 13. *Shewing how to reduce hypothenuſal Lines to horizontal.*

If the Lands to be plotted are hilly, and not in any one Plane, the Lines meaſured cannot be truly laid down on paper without being reduced to one Plane, which muſt be the horizontal, becauſe the Angles are taken in that Plane.

In viewing my objects, if they have much altitude or depreſſion, I either write down the degree and decimal ſhewn on the Double-Sextant, or the links ſhewn on the back-ſide, which laſt ſubtracted from every chain in the ſtation-line, leaves the length in the horizontal Plane; but if the degree is taken, the following Table will ſhew the quantity.

A Table of the links to be ſubtracted out of every Chain in hypothenuſal Lines *of ſeveral degrees altitude, or depreſſion, for reducing them to* horizontal.

Degrees	*Links*	*Degrees*	*Links*	*Degrees*	*Links*
4,05	¼	14,07	3	23,074	8
5,73	½	16,26	4	24,495	9
7,02	¾	18,195	5	25,84	10
8,11	1	19,95	6	27,13	11
11,48	2	21,565	7	28,36	12

Let

Let the firſt ſtation-line in *Fig.* L really meaſure 1107 links, and the Angle of altitude or depreſſion be 19°,93; looking in the Table I find againſt 19°,95 is 6 links, now 6 times 11 is 66, which ſubtracted from 1107 leaves 1041, the true length to be laid down in the Plan.

Note, All *Surveyors* do not agree as to the Contents of hilly grounds; for Some ſay, that as the Tenants have the produce of the whole Superficies, the quantity ought to be according to the ſuperficial Content, altho' the horizontal only is to be plotted: but Others, with more juſtice, argue, that ſince all vegetables grow upright, as much would grow on the horizontal Plane, if thoſe hilly grounds were level, as there do on thoſe convex Superficies; therefore all theſe ſhould be reduced to the horizontal, and ſo plotted, and the quantities deduced therefrom; for by the former the ridges and furrows in plowing make more land, which not being allowed, it muſt be more juſt to reckon only the horizontal Quantities.

CHAP.

CHAP. IV.

Shewing how to ſurvey and plot ſeveral pieces of land lying together, as a Farm, Manor, &c. *by obſervations taken with the Theodolite before deſcribed.*

Sect. 1. *That the Methods propoſed by former Writers have not anſwer'd in large Surveys.*

HAving already mention'd ſeveral Methods of meaſuring and plotting a ſingle Field, I ſhould now proceed to ſhew thoſe commonly treated of and uſed in the plotting many parcels together, as a *Farm*, *Manor*, *&c.* but as none have anſwer'd in the Practice, in large *Surveys*, I think the Reader would be little advantaged by their truth in Theory.

Believing it ſo in all publiſht on *Surveying* before that in the *quarto* Edition of Mr. *Edward Laurence*'s *Duty of a Steward*, the 36th Article, which treats of *Surveying*, was compoſed by me, and has my name inſerted; and ſo was the Table of *Timber-Meaſure*; both which I might here reprint: but as Mr. *Siſſon* has

has ſince ſupplied the latter, by a new circular Inſtrument (of whoſe Uſes, and the Sliding-Rule's, I have written a ſmall Treatiſe, which he will ſoon print and publiſh) and made ſome alterations as to the former in his Theodolite, I ſhall now only ſhew more fully my Method of ſurveying and plotting many parcels lying together, and the great improvement made therein, by Mr. *Siſſon*'s new Protractor, and Scale of equal parts.

Sect. 2. *Shewing how to ſurvey ſeveral parcels lying together, as a* Farm, Manor, &c.

Let *Fig.* N be part of an incloſed *Manor* to be ſurvey'd, and plotted.

Firſt, I walk round the land, either juſt within or without, ſetting up objects for my ſeveral Stations (as I go on) ſo, that the next following may be ſeen at each, and ſometimes the next two, whereby a planting of my Theodolite is often ſaved, like as in ſurveying *Fig.* L.

Having made holes, and ſet objects upright in them all round, that at the laſt the firſt may be ſeen, I now go round again at one Cloſe diſtance within the land, ſetting up more objects to be ſeen from ſeveral of my Stations near the outſide bounders.

As ⊙ 10 is ſeen at ⊙ 9, I do not plant my Theodolite at either of thoſe objects in the South-weſt Cloſe; for viewing the one from ⊙ 9, and the other from ⊙ 10, that Cloſe may be

be truly plotted by measuring the three Lines, and so will the place of all the objects set up one Close distance within the land.

These objects, as well as the former, being all set upright in the holes made at each, tho' I always observe the stick near the ground, if I can, I now plant my Theodolite at ⊙ 1 directly over the hole, by the plumb-line hanging under it's center; and making the Limb horizontal, which I do at every ⊖, I turn it to have the Needle point to the Variation; then by the pinion I turn the Indexes till the upright wire in the Telescope cuts exactly in the midst the object at ⊙ 58; now I write down last ⊙ line, with the degree and decimal shewn by the chief Index, *viz.* 5°,93 West, because when my Theodolite shall be planted at ⊙ 58, then ⊙ 1 will be so much on the West side of the Meridian; then I turn the Indexes to make the same wire cut exactly the object at ⊙ 2, and screwing fast the Index, I write down 1 ⊙ line ... 86°, 27 West under the former; now taking up my Theodolite, I send it to ⊙ 2, and set up again the object at ⊙ 1 by a plumb-line as before, and measure from it with my Chain to ⊙ 2, writing down my offsets as I go on, like as in measuring *Fig.* L.

If in viewing from ⊙ 1, I could not see the object-stick at ⊙ 2 near the ground, and coming to it find the object alter'd, I make a new hole directly under it, and stop up the old one, and plant my Theodolite exactly over this new hole,

hole, and making the Limb horizontal, I turn it to have the wire cut exactly the object at ⊙ 1; now looſening the Index, I turn it to have the wire cut firſt the object a Cloſe diſtance within the land, and then the object at ⊙ 3, ſcrewing faſt the Index, and writing down the degree and decimal for each; now I meaſure on to ⊙ 3, and leave the meaſuring to my by-objects, till after I have plotted my circuit ſtation-lines; and thus I proceed from each ⊙ on to the next, till I have view'd all my objects, and meaſured all my circuit ſtation-lines, which I firſt lay down in my Plan, to ſee how they will cloſe, and if the laſt meets in 1 ⊙ point, or very near, it proves them plotted very near truth; then I plot the offsets, and thro' them draw the outſide bounders, with the croſſing into each Cloſe, if within the land, or the abutting to the bounder, if without the land, then I draw dry lines from the proper Stations, for the by-objects view'd a Cloſe diſtance within the land.

As by this method I often take in a circuit of a large compaſs, and have many Stations, with many by-objects within it, I ſometimes (after having plotted the out-bounders, and dry lines for the by-objects) take a ſketch of them into the fields with me; for by it I can have a better Idea of my work within, and draw a repreſentation of every new line I meaſure, till I have meaſured every particular line.

In meaſuring within my circuit, I never truſt to the truth of any line without being able to

prove it, by meaſuring every line, and finding all the parts equal to the whole; and hereby I plot the whole, and every particular, as truly in it's due Poſition, as if but one Cloſe; for I meaſure and plot every particular, and prove the truth of each, by their filling up the whole.

If my firſt circuit ſhould take in but part of the land lying together, I could proceed in making a new circuit from any of the Stations; for if the land in *Fig.* N was as long again Weſt as appears, and the ſecond object in the South-weſt Cloſe was a fit ⊙ for beginning my next circuit, I ſhould plant my Theodolite there, and put the chief Index to the ſame degree and decimal it was at, when viewing that object from ⊙ 10, and make the wire in the Teleſcope cut the object at ⊙ 10; then I may proceed, as in the former circuit, round to meet ⊙ 25; and alſo another circuit more North may come to meet ⊙ 35; and at every ⊙ the Needle (if true) will point to the Variation.

If I had a Survey to make of many thouſand Acres lying together, my firſt circuit would take in a great part in the main body of it, and I ſhould leave for freſh circuits ſuch parts as branch out from it; but if a Road or Lane ran thro' it, in which the ſtation-lines need none be ſhort, my firſt circuit would be in it; and if otherwiſe, I ſhould include the Lane within a larger circuit, and afterwards plot the Lane by ſtation-lines meaſured in it, and offsets made to the hedges on both ſides.

If

If ſuch care is taken to have the objects and Theodolite at every ⊙ exactly over the hole, and the wire in the Teleſcope to cut the object at each, it may be expected, that coming round, and planting my Theodolite at ⊙ 58, the Index ſhall (on turning the Teleſcope to make the wire cut the object at ⊙ 1) ſhew the ſame degree and decimal as when planted at ⊙ 1 cutting ⊙ 58; and that it will do ſo, I have often experienced; and I ſhould not fear in a circuit of ten Miles and 200 Stations, but that the Index at the laſt ⊙ would be nearer than two decimals; and then that which is more extraordinary, I could plot theſe 200 ſtation-lines ſo truly, as to cloſe much nearer than half a Chain, tho' that be in my Plan but $\frac{1}{8}$ of an inch; and thus I could be ſure of detecting an error of one Chain at firſt plotting the circuit in any one of the ſtation-lines; for that is the error we are moſt liable to, by forgetting to count the laſt arrow.

This ſome years ago (when I was writing the Article before-mention'd, for publication) ſeem'd ſo to Mr. *Siſſon*, that he thought I ſhould not aſſert the doing it ſo near in a circuit of four Miles, till I had convinced him by an experiment thrice perform'd; for I made a circuit anſwering to near $3\frac{1}{2}$ Miles twice to meet in the ſame fine point-hole, and that fartheſt off from meeting was viſibly nearer than anſwer'd to two yards on the land.

Sect. 3. *Shewing how to plot a large Circuit.*

Having paper large enough, by paſting two or more ſheets of large paper together, I firſt draw a dry line croſs it for a true Meridian, marking it with N and S; then I pin down a large circular Protractor, with it's diameter exactly over this line, and making the center-point therein, I ſet off all the Angles, as well thoſe of the by-objects as the ſtation-lines, at this once fixing on both ſides the diameter, whereby I have with the center three points to apply my parallel Ruler to, for transferring each to it's proper ⊙; as *Sect.* 9. and 12. of *Chap.* III.

I have two long parallel Rulers, which open the one to the right, and the other to the left; and as there are none made ſo true, but, in many ſhiftings, will vary ſome little from a true parallelism, I take care to know in what manner each is liable, and allow for it; and hereby is prevented that continued increaſe of errors, which all *Surveyors* have ever heretofore been liable to, in ſetting off their Angles by laying their Protractor down on every new-drawn ſtation-line to ſet off the ſucceeding; ſo that ſuppoſing forty ſtations, they had thirty-nine times laying down their Protractor, and what errors that might produce, may be conceived by allowing a ſmall error the ſame way in every one, and taking for an Example a regular Polygon.

Now

Now let it be required to plot a regular Polygon of forty Sides of 700 links each, by ſetting off the Angle at each corner, *viz.* 171°, and allow an error of 3′ made the ſame way in each Angle, by laying down the Protractor, ſetting off the Angle, and drawing each Line; now by the continued increaſe of this ſmall error of 3 Minutes 39 times, the end of the fortieth Side will be varied from cloſing above five Chains; whereas by my Method, I can plot ſuch a Polygon to cloſe almoſt in the very point.

This therefore I have called my new Method of plotting Surveys, far excelling in exactneſs all other; which I ſtill believe no One ever practiſed before me from Angles taken on the Limb of the Theodolite; and what put me upon trying it, was, my having in the year 1724. taken a circuit near the bounder of a *Noble Lord's* Park I then ſurvey'd, in which the ſum of my ſtation-lines was near five Miles, and upon trial to plot theſe in the common Method by a half-circle Protractor of four Inches radius, I found them to vary much from cloſing; then I began again, and plotted them backwards, and found them to vary the other way as much, which gave me reaſon to conclude, that the Lines were truly meaſured on the land, as well as the Angles, which I had proved by the ſum, and examined by the Bearings, which I had alſo taken by the Needle; wherefore plodding how to lay down theſe lines trueſt, and having a parallel Ruler with me,

me, for reducing irregular figures each to one Triangle, gave me the opportunity of trying this Method, which finding to anſwer, I have practiſed ever ſince.

I need not ſhew how to plot each Cloſe in *Fig.* N to any One, who has with knowledge read all the former Methods of plotting a ſingle Field; for if he conſiders the prick-lines to be the meaſured Lines, he may ſoon ſee, that when the circuit ſtation-lines, and the others (whoſe Angles were taken at thoſe Stations) are plotted, the reſt are eaſily had therefrom, by the method of interſection, if a meaſured Line be added acroſs ſome of the Cloſes, and it be poſſible to ſee on the land the length of each line in the *Scheme*, like as in plotting a Field meaſured by the Chain only; but if the land is hilly, that the lengths of ſeveral can't be ſeen, then I plant my Theodolite at one of the objects a Cloſe diſtance within the land, and ſo go over acroſs by new ſtation-lines near the bounders of the inner Cloſes, which I may do here alſo, and begin at the by-object ſeen from ⊙ 13, and go on acroſs as number'd to view again one of them taken at ⊙ 48; then I may plant my Theodolite at the by-object in the Lane taken at ⊙ 4, and ſo make on therein as number'd to view again that ſeen from ⊙ 62; when theſe are done, I may plant my Theodolite at the by-object taken at ⊙ 33 within one of the Cloſes near to the narrow Lane ſide, and ſo make on thereby as number'd to view again that ſeen from ⊙ 63; now as the Angles

of

of theſe are taken after the others are plotted, the Protractor muſt be pinn'd down once more for theſe alſo; when theſe are plotted with the Lines to the by-objects view'd from them, it is likely the reſt may be done by interſection; but if they can't, I make more Stations, till the reſidue can.

The black curve lines are for the bounders of the ſeveral Cloſes (which commonly are the ditches on the outſide of the hedges) to every bend of which I take offsets from the meaſured lines, like as in meaſuring *Fig.* L; but I have not ſhewn them in *Fig.* N, becauſe all can't be ſhewn that muſt be taken: where a ſmall Brook is the bounder, I take the middle; but if a River, I take to the ſide, and if within my Survey, I ſhew it's true breadth.

Some may think, I ought to have ſhewn an Example of a real Survey, or to have given numbers like my field-book for plotting this; but having been ſo full in one Field, I think it needleſs: however, I have mention'd Numbers having no error, in a regular Polygon of forty Sides, whole chains each, and whole degrees at each Angle, both which may be ſet off the truer by having no odd parts, which ſuch may firſt try with; and each Angle of any other regular Polygon is had by dividing 360 by the number of Sides, for that quotient is the ſupplement of each to 180.

If in hilly land I would continue any Line longer than the place I could at firſt ſee to, I place an object between exactly in the Line,

as

as I did thoſe at *m* and *q* in *Fig.* F; and then I can continue it as far on farther as I can ſee the new object; and if here I ſet up another, I may continue it as far on farther as I can ſee the firſt object ſeen to; and thus a Line may be continued quite over a hill.

Sect. 4. *Containing a Deſcription of Mr.* Siſſon's *new Protractor, and Scale of equal parts, as I communicated it to the* Royal Society *in* May 1736.

Mr. *Siſſon* has lately invented and made a new Protractor for drawing the ſtation-lines of a Survey, whoſe Angles have been taken by his Theodolite, and alſo a new Scale of equal parts for the ſetting off their lengths, and both with more truth and accuracy than had hitherto been poſſible by other Inſtruments.

The Protractor is a braſs circular plate of 18 inches diameter, whoſe limb is divided into half degrees by the ſame method as that of his Theodolite is into whole degrees, and it is in the ſame manner number'd by tens to twice 180; theſe half degrees are applied to an Index-plate with a double ſet of *Nonius's* diviſions, the one for every half decimal of a degree equal to three minutes, and the other for every thirtieth of a degree equal to two minutes, and to which any part of the limb may be brought, by turning the circular plate round the fixt center-pin upon which it is moveable.

The

The outward edge of the Index-plate is parallel to a tangent touching the circular limb in the point where the Index ſhews the diviſion; to this outward edge is applied a Ruler in form of a T, like thoſe uſed on common drawing-boards, the upper part of this T is of braſs, and the lower of ſteel, by the ſide of which laſt the ſtation-lines are drawn on the Plan, a ſquare foot of paper being for that purpoſe firſt properly fixt on the middle of the circular plate, and when any line extends beyond the limits of that ſquare foot, that paper may be taken off, and fixt on again with another cloſely adjoining to it, in ſuch a manner as that half a foot only of each ſhall be ſeen, whereby the Plan is with the greateſt exactneſs carried on into the next ſquare foot; and thus it may with the ſame accuracy be extended to any ſize, by the perpetual adding ſquare feet of paper, ſo long as ſhall be needful, without paſting together; for being all cut exactly to the ſame ſize, they will, when properly laid down on a Plane, exactly touch and adjoin each other.

The new Scale of equal parts may be made to any proportion; that here ſhewn contains two Scales, the one of 3 chains, and the other of 4 chains to an inch, as being what are moſt frequently uſed; each of theſe Scales is curiouſly divided to every 10 links or tenths of a chain, which are again ſubdivided by an Index with *Nonius*'s diviſions into ſingle links; and this Index carries the protracting-pin ſetting

off the lengths of the ſeveral ſtation-lines on the Plan, in the manner of a beam-compaſs: and by this Index the intermediate diviſions are ſo well eſtimated, that One may be aſſured of not erring a ſingle link in the ſetting off any diſtance within the extent of the Inſtrument, which link in the leſſer Scale is but the 400th part of an inch, and the extent is 48 chains; by the means of theſe Inſtruments the Angles and Lengths of the ſtation-lines of a *Survey* may be laid down on paper with as much exactneſs as they can be meaſured on the land with the beſt ſurveying Theodolite and Chain; and hereby not only the *Surveys* of *Eſtates*, but alſo of *Countries*, may be plotted with greater truth and accuracy than was ever heretofore poſſible.

Sect. 5. *Shewing how to plot a large Circuit by this new Protractor and Scale.*

Firſt, I fix down a ſquare foot of paper on the circular plate, and write N next the ſide for the North; now I bring the degree and decimal, either on the Eaſt or Weſt ſide of the Meridian to the Index, according to what I wrote againſt 1 ⊙ line, and ſcrew it faſt; then by the ſide of the T Ruler I draw a dry line where I think beſt, and ſet off therein by the new Scale the length of the firſt ſtation-line, making a ſmall black-lead circle round each ⊙ point, as before directed; now unſcrewing the Index, I bring the degree and decimal of 2 ⊙ line to the

the Index, and ſcrew it faſt; then by the T I draw a dry line from ⊙ 2, and ſet off therein at it's juſt diſtance by the new Scale ⊙ 3; now unſcrewing the Index, I bring the degree and decimal of 3 ⊙ line to it, and ſcrew it faſt; then by the T I draw a dry line from ⊙ 3, and ſet off therein ⊙ 4; and thus I proceed on (if the foot of paper will hold it) till I come round to ⊙ 1, always drawing the dry line from each ⊙ towards the right at the top of the T, whereby each line is the more truly drawn from each ⊙ point.

When one foot of paper will not contain the whole, and I find the ſtation-line will run off the paper, I looſen and take up the paper then doubling it, and another foot, each exactly croſs the middle, I fix them down together as one foot; and ſo the ſtation-line is ſet off at it's juſt diſtance, as if on the ſame piece of paper; and thus the whole circuit, or other circuits adjoining, may be continued on as many ſquare feet of paper as I need.

The circuit ſtation-lines being plotted, and meeting exactly in 1 ⊙ point, I bring the degree and decimal for each by-object ſucceſſively to the Index, and draw dry lines from the proper ⊙ for each; and after meaſuring their lengths on the land, I ſet off them alſo by the new Scale; and alſo the lines to be plotted by interſection: indeed the former Scale is moſt ready for plotting the offsets from all the ſtation and other meaſured lines.

Sect. 6. *Of measuring in Common Fields.*

When ſingle Lands in Common Fields are meaſured, it is uſual to meaſure the length down the ridge, and to take the breadth at the two ends, and about the middle, adding the three breadths together, and taking a third of the ſum for the mean breadth: but this is not a true method, unleſs the middle be a mean between the two ends; for ſome are broadeſt in the middle, and others are the narroweſt, ſo that no certain Rule can be given; wherefore the *Practical Surveyor* muſt uſe diſcretion, and meaſure the breadth oftner, where he ſees occaſion; but not to take it too near the ends, becauſe the turning of the Plough generally alters the breadth there, from what it is at a little diſtance.

The ſeveral Furlongs or Shoots in Common Fields I plot as the Incloſures in *Fig.* N, by ſetting up objects near the bounders of each, and taking the Angles by the Theodolite round the whole Field or Fields, as before directed; in meaſuring the ſtation-lines, and others, I write down my paſſing out of one Man's land into another's, at ſuch a number of links as it happens; but in many Common Fields, where there are many Freeholders, and Tenants, all having ſmall parcels, it is very tedious work, and if not plotted by a large Scale, it will be unintelligible; if one Gentleman's land only is plotted, the names of the Free-

Freeholders on each Side of every parcel muſt be written down in the Plan; but in this laſt caſe, it is more common to meaſure the Lands, and to make a Terrier of them, denoting their length, mean breadth, and quantity, with the names of the perſons adjoining on each ſide, and ſo to make no Plan of them.

Sect. 7. *Of dividing Lands.*

Having in *Chap.* I. *Sect.* 4. ſhewn how I reduce any multangular Figure to one Trapezium, and caſt up the Content, which underſtood, there can be no difficulty in dividing any plotted parcel in any manner commonly required; for knowing the quantity of the whole, I firſt divide it by gueſs in the manner required, and caſt up the quantity, and what it differs, I add to or take from it; which being very eaſy, needs no Example.

Sect. 8. *Of changing Statute-Meaſure into Cuſtomary*, & è contra.

It is cuſtomary in ſome parts of *England*, to have 18, 21, *&c.* feet to a pole, and 160 ſuch poles to an Acre; whereas by the Statute $16\frac{1}{2}$ feet make a pole.

Now to change one Meaſure into the other, the proportion is, as the ſquare of one is to the ſquare of the other, ſo are the Areas in an inverſe ratio.

If a parcel of land meaſures by the ſtatute-

pole

pole 144 Acres, the ſame by a pole of 18 feet will meaſure but 121; for that is as the ſquare of 33 to the ſquare of 36 (the half feet of each pole) by the inverſe Rule.

Sect. 9. *Of reducing Plans.*

The moſt common way to reduce a Plan, is to draw it full of ſquares with a black-lead pencil, and then to draw the like number on the paper for the leſſer Plan, but ſmaller in proportion as the Map is to be leſs; then every particular in the greater may be drawn in the leſs by ſight; but the beſt way is to uſe an Inſtrument called a Parallelogram, compoſed of five bars and two ſupporters joined together; which (by ſliders moveable to diviſions numberd alike on three of the bars) is ſet to any proportion between equality, and 1 to 10 in the Scale, or 1 to 100 in the Area. See the *Fig.* fronting the Title page.

Mr. *Siſſon* has made many of theſe in braſs, for copying and reducing ſmall Prints; but they are alſo well adapted for copying or reducing the Plans drawn on his new Protractor, or on his improved Plain-Table; for they being each but one ſquare foot, may hereby be copied in any ſize between that and $\frac{1}{100}$ of a foot.

The ſliders being put to the ſame reducing number on the three bars, and the ſupporter *c* fixt moveable in a center hole made thro' a ſmooth Table, and the Plan and fair paper fixt

fixt oppoſite to each other touching the ſupporter *c*, if with the Tracer *b*, I trace all the lines in the Plan, the Pencil *a* will mark the fair paper with lines of the ſame ſhapes, only different in length, as the number (the ſliders touch) differs from 10; for if the ſliders touch 5, each line will be but half, and if they touch 2, but $\frac{1}{5}$ of thoſe in the Plan.

Sect. 10. *Of making the fair Plans.*

Firſt, I lay the fair paper or vellum on a clean ſmooth Table, then I lay over it the rough Plan, and place two or more weights thereon, to keep it from altering, which weights I move (as I pleaſe) to lay next under any part of the rough Plan blackt paper with the black ſide downwards; then with my pointrel I trace the bounders of every parcel, whilſt the blackt paper is under each, and that imparting of it's black, there will be ſeen on the fair paper or vellum all the lines traced, which I then draw with fine ink-lines, or make hedge-rows thereon, where there are hedges, and darken one ſide, and draw a ſhadow of each buſh and tree with Indian ink, which at 3 or 4 feet diſtance look as if they were printed from a copper-plate; which method I had from Mr. *Edward Laurence:* indeed I colour Rivers, Brooks, and Ponds with a light blue green, and in Common Fields or Meadows, where the Lands are ſeparated with neither hedge nor ditch, I make thoſe bounders with prick-

prick-lines, and colour the inſide edges with a light yellow, and ſoften it off to be loſt by degrees to the white of the vellum.

I generally draw my fair Plans on the beſt vellum, that being handſomer, and much more durable, than paper paſted on cloth; whatever *Buildings* are on the Eſtate, I lay down the ground-plat only, and that I often colour like brick: indeed the *Churches* and *Windmills* I draw in perſpective, and ſhade them with Indian ink.

As to my references, I write the name of each parcel within it, and put down the quantity under the name, and a letter or other character of a beautiful red over it, to ſignify the Tenant; then by the name of each parcel being written in a book under the ſame letter or character as in the Plan, with the quantity in it's proper column, whether arable, meadow, or paſture, commonable, or encloſed, and the viſibility of the red letter, both the Plan and book, are eaſily compared together; and there is one conveniency in this method, that upon any alteration, it is eaſy to eraſe one letter, and put in another; whereas thoſe who repreſent the different *Farms* by different colourings, thereby make them incapable of any alteration.

Somewhere near the top, I write the Title of the *Survey*, and near the bottom the Scale by which it is plotted, and juſt over, what Scale it is; then in any void place I draw the Compaſs neatly ſoften'd with Indian ink, and place

place a flower-de-luce for the North, and letters for the other cardinal points; I alſo write on the outſide of the bounders the names of the perſons having the lands adjoining, whereby my fair Plans are generally pretty full of writing, which I do as neat as I can.

When I ſurvey the whole of a large *Eſtate*, I draw them on ſeveral ſkins of vellum, and by paſting them to guards, have them bound up in *folio*; and then each Map may lie open, and no part drawn into the binding; and hereby a large *Survey* is moſt ready for uſe and carriage, is kept cleaneſt, and will be moſt durable.

A Specimen of my fair Plans may be ſeen at Mr. *Siſſon*'s, and alſo at *Richard's Coffee-Houſe, Temple-Bar.*

CHAP. V.

Containing general directions for the Survey of a County, *and taking the Plan of a* City, Town, *&c.*

Sect. 1. *Shewing how to ſurvey and plot the Roads thro' the* County.

SUppoſing I have two of Mr. *Siſſon*'s Theodolites, a Meaſuring-Wheel that ſhews miles, furlongs, chains, and links, a Chain, the new Protractor and Scale, and four Aſſiſtants; I begin at ſome place near the middle, where ſeveral Roads meet, and from whence I can proceed ſeveral ways to the outſide of the *County*, and here I plant my beſt Theodolite (if there be any difference) and after bringing the degree of Variation to the Needle, I turn the Indexes and Teleſcope to view objects ſet up in all the ways as far as I can ſee, and write down the degree and decimal for each, and mark each place to find it again, when wanted; now taking up my Theodolite, I ſend it to ⊙ 2, and ſetting up an object at ⊙ 1, I meaſure from it with the Wheel to ⊙ 2, taking heed to put the hands to the begin-

beginning of the numbers, whilſt the axis is even with, or over ⊙ 1; then if puſht on to ⊙ 2, or any place between, the hands will ſhew the chains and links, nearer truth than can be plotted by ſo ſmall a Scale as muſt be uſed.

Whenever any thing at a diſtance worthy of remark happens to be ſeen at ſome place in any ſtation-line, that I can't ſee at any two Stations, I write down the numbers the hands of the Wheel point to, when over that place; then puſhing the Wheel a little on, I plant my other Theodolite there, and make the Index agree to my Station-Theodolite (which I never alter, but at my Stations) then turning the Limb to have the upright wire in the Teleſcope cut the object at either ⊙, I turn the Index that the ſame wire may cut the thing to be remarkt, and write down it's true Bearing; then I meaſure on to the next ⊙, if nothing elſe of the like nature happens on either ſide of the Road; but if there does, the like work muſt be repeated; and as this will often happen, I muſt have a Man ready with an object about the middle towards the next ⊙, that as ſoon as I have view'd that at the ⊙, I may direct him to ſet up his exactly in the ſtation-line, whereby I can keep the line more truly in puſhing on the Wheel, and alſo plant the Theodolite in the line readily, whereſoever wanted.

As two Bearings muſt be taken for every diſtant thing, which I ſhew in it's true place, ſo every one whoſe Bearing is once taken, I

endeavour to find the beſt place for taking a ſecond; I don't only go once, and ſet up my objects, and ſo come back again, but I before ride it forwards and backwards, that I may have a full Idea, and know how every thing can be beſt perform'd.

I take the Bearing of every thing needed at my Stations, with my Station-Theodolite, where-ever I can; for when that is planted at any ⊙, I can take the Bearing of every thing within view, before I fix the Index for the next ⊙; and tho' the Angle at the interſection be the acuter, I ſtill do it, becauſe the Bearing is the more truly taken, and by the new Protractor I can plot it very near truth.

As I meaſure on in the Road, I note every Road and Lane that turns out of it; and whether it is on the right hand, or the left, and to what place it leads; and whether it inclines forward, or backward, or is nearly at right angles, for which I make marks in my book: but if it is a Road that muſt be ſurvey'd, I plant my Theodolite, and take the Bearing, and meaſure to ⊙ 1 in it, and mark both places to be found again.

If I paſs over any *Bridge*, or thro' any *Ford*, I mention it, with the name of the River, and from whence it comes, and whither it goes; but if I muſt ſurvey the River, I plant my Theodolite, and take the Bearing, and meaſure to ⊙ 1 made at the ſide of it, both upwards and downwards, and mark them alſo.

Where-

Where-ever I begin to aſcend or deſcend, arrive to the top or bottom of any hill, I note it, with the degree of aſcent or deſcent, that I may plot the horizontal lines.

I note where I enter any *Town* or *Village*, and where I go out; whether the houſes adjoin, or are diſtant; whether on the right, or left, or on both ſides, with it's right name; and, if a *Market-Town*, the Market-day.

I note all the *Mills* I meet with, and *Churches*, with their perſpective form, and all *Churches*, *Wind-mills*, *Great Houſes*, *&c.* that are remarkable at a diſtance, and can be ſeen at two places in the Road, I take their Bearing from both.

Thus I proceed for 3 or 4 days, entering every thing in a plain manner, and with all poſſible caution not to make any miſtake; then I plot theſe obſervations, and in the mean time my Aſſiſtants may drive down a ſhort ſtake in the place of every object left, and endeavour to ſet out freſh Stations with them, which I can ſoon alter, where needful.

Having the new Protractor, with a ſquare foot of paper fixt on it, markt with N for the North ſide, I bring the ſame degree and decimal to it's Index as I took with my Theodolite for 1 ⊙ line, and ſcrew it faſt; then making ⊙ 1 where I judge moſt convenient, I draw by the T Ruler a dry line from it, and ſet off therein by the new Scale ⊙ 2, both at it's juſt diſtance, and at ten times that diſtance; then looſening the Index, I bring the degree

and

and decimal of 2 ⊙ line to it, and ſcrew it faſt; then by the T Ruler I draw a dry line from each ⊙ 2 point, and ſet off in both ⊙ 3, the one at it's juſt diſtance, and the other at ten times that diſtance; and thus I go on with the reſt, till that by the enlarged Scale will go off the paper; now I examine by the T Ruler, if the two laſt made ⊙ points are in the ſame line from ⊙ 1, and by the Scale if the diſtance of one is exactly $\frac{1}{10}$ of the other; and if otherwiſe, I make it ſo; for increaſing the Scale ten times, I ſet off each diſtance with but $\frac{1}{10}$ error.

This ⊙ being right, I go on from it as I did from ⊙ 1, both by the ſmall Scale, and by the enlarged, till the line by the laſt will go again off the paper; then I do as before nine times; after which I looſen the paper, and take it off; then doubling it, and another foot, exactly croſs the middle, I fix them on together as one foot; now I go on as before, the ſame as if it was but one piece of paper; ſo that by theſe means I plot theſe lines much truer than the like for any *County* ever were, or indeed could be.

I draw alſo dry lines for every diſtant thing obſerv'd, and at the interſection place the perſpective figure of it, whether *Church, Windmill, &c.*

I repreſent the Road by a line on both ſides of the ſtation-lines, at a ſuitable diſtance without taking offsets, becauſe the Scale muſt be too ſmall to allow the true breadth; I make theſe lines black, where the Road is bounded by

by hedges; but where it is an open way over a *Common, &c.* I make them prick-lines, and write the name of the *Common, &c.* and ſo I do, if the Road paſſes thro' a *Park, Wood,* or *Chaſe,* and make ſmall trees on both ſides, where it is woody.

Where the Road paſſes thro' a *Ford* without a *Bridge,* I draw the River acroſs the Road; but if with a *Bridge,* I draw it in part only; but if a *Bridge,* and no *Ford,* then I draw the River only to the outſides of the Road; I write the name of the *Ford, Bridge,* or River, and from whence the water comes, and whither it runs, unleſs I am to plot it, and then the Plan will ſhew it.

I write the quality of the Road, whether good or bad; and where hilly, I ſhew by ſhadowing it, and the land on both ſides, with Indian ink; where any Road or Lane turns out, I make two lines for it with ſuch inclination as I obſerv'd, and write to what place it firſt leads; I ſhew alſo the *Towns, Villages, Churches, Mills, &c.* that I noted in meaſuring; and thus the Road will be agreeably fill'd with remarks.

Sect. 2. *Shewing how to plot any River or Brook in the Survey of a* County.

If I have the River or Brook in ſurveying the Road, I begin at either ⊙ 1, already meaſured to at the ſide of it, where planting my Theodolite with the Index to the ſame degree

and

and decimal as taken in the Road, I turn the Limb to have the wire cut the object ſet up in the Road, where this ⊙ was obſerved; then I turn the Indexes to obſerve ⊙ 2, and go on as before in the Road; but here I need not mind ſmall bends, only great ones; at each of which objects muſt be ſet up by the River-ſide, for the ⊙ places, till I come to it's riſe one way, and it's falling into the Sea, or another River, the other way; or elſe to it's entrance into the *County* one way, and it's going out the other.

Here alſo I uſe two Theodolites, one for the Stations, and the other for obſerving between; if the River is broad like the *Thames* near *London*, it's breadth muſt be determined by twice obſerving the ſame things on the bank of the other ſide in ſeveral places, like that of other remarkable things.

The manner of meaſuring and plotting being the ſame as laſt ſection (except that the Chain will be moſtly uſed in meaſuring, and that the large bends will often cauſe my ſetting up two objects forwards within view, whereby I ſhall ſo often ſave planting my Theodolite at the firſt of them) I need not repeat it; only that here I ſometimes take offsets to the middle, unleſs it's breadth is to be regarded, and then I take them to the ſide only.

I note every *Bridge*, *Mill*, *Sluice*, *Lock*, *Flood-gate*, *Cut*, *&c.* that I meet with on the River, and all Rivers and Brooks coming into it; and if they are to be plotted, I make ⊙ 1

as

as far up by the ſide of them as I can ſee, and meaſure to it.

I note all the *Towns* and *Villages* that the River runs thro', or paſſes by; and I obſerve all the *Churches*, *Wind-mills*, *&c.* that happen twice in my view from the River-ſide.

When I have plotted this River, and all the remarks taken, if it is for the *Survey* of a *County*, I proceed to meaſure ſome of thoſe that run into it; becauſe all thoſe ought to be plotted as exactly as this.

Note, Narrow Roads and Lanes may be ſurvey'd in the fields by one ſide of them, where the views may be the longer, and better opportunities had for the diſtant remarks.

Sect. 3. *Containing farther directions in the Survey of a* County.

Having plotted all the Roads and Lanes, Rivers and Brooks needed, and therewith the *Towns*, *Villages*, *Churches*, *Great Houſes*, *Wind-mills*, *&c.* obſerv'd, I now ſurvey the outſide limits of the *County*, beginning from the laſt object in my Survey of one of the Roads or Rivers, and proceeding to that of the next Road or River; and ſo I go on ſucceſſively, till I have got quite round the whole *County*, obſerving with my two Theodolites, and meaſuring with the Wheel or Chain, as ſhall be moſt convenient.

Theſe being plotted alſo, I now ſurvey from ſome Road plotted into thoſe parts that have

no remarks in my Plan, and ſo I fill up with new remarks all the void places, whereby I ſhall inſert all *Parks*, *Foreſts*, *Lakes*, *Villages*, *Great Houſes*, *Churches*, *Wind-mills*, *&c.* that I did not meet with, nor ſee, in ſurveying the Roads, Rivers, and Limits; by planting my Theodolite on high Hills or Steeples, I may ſometimes ſhorten my work in theſe particulars.

Laſtly, I take the *Latitudes* in 3 or 4 places of the *County*, and make a Scale of the Minutes of *Latitude* and *Longitude* round the outer edge of my Plan, drawing lines acroſs to ſeparate every five Minutes.

Sect. 4. *Directions for taking the Plan of a* City *or* Town.

The Method of work in this is the ſame as ſurveying in a Lane between encloſed lands; for the offsets to the *Houſes*, *&c.* are taken from the ſtation-lines on both ſides of them, and I place them in my book to the right or left of the ſtation-line number, as they are, when I ſtand on my Chain looking back to the ⊙ meaſured from.

Firſt, I ſet up objects in ſight one from another, at as great diſtances as I can, thro' all the chief Streets, that lead out of one into another, whereby I encloſe the by-lanes, alleys, *&c.* lying between them, and I ſet ſome of theſe objects againſt the ends of the by-lanes, *&c.*

&c. to view down them, when my Theodolite is planted at thoſe objects.

Theſe objects may generally be ſhort ones of but 2 or 3 feet long; for the ſhorteſt are eaſieſt ſet upright; I make holes for them between the Pebbles with a pointed Iron of 6 or 7 Inches long, and with a hammer both drive it in, and looſen it.

As ſoon as I have meaſured my circuit ſtation-lines, I ſend One to take up theſe objects, and drive down a ſhort ſtake at each, to find them again, when wanted.

As the manner of uſing the Theodolite, meaſuring and plotting the ſtation-lines, and thoſe thro' the by-lanes, alleys, *&c.* and the offsets, are as before, I need not repeat them; but may add, that I uſe a larger Scale than in ſurveying land, and lay down the Ground-Plat of all the *Buildings* in their due ſhape and ſize, and ſhade them deep with Indian ink; and I write the names of the Streets, Lanes, and Alleys in them.

The Title, Scale, Compaſs, and References may be like the printed Maps of the City of *London*; therefore a Scale of yards or feet may be beſt in the fair Plan.

Sect. 5. *Shewing how to find a* Meridian-Line *by obſerving the Sun, or a fixt Star with the Teleſcope on the Theodolite.*

Suppoſing the time not far off from the Summer Solſtice, I chuſe a clear day, when

the Sun appears bright, about four hours before Noon, and provide a ſmoked or colour'd glaſs to guard my eye from damage; then planting my Theodolite, and adjuſting it to move very truly horizontal, I move the Index horizontally, and the Double-Sextant vertically, till the croſs-wires in the Teleſcope both touch the edge of the Sun's body; then I write down the degree and decimal ſhewn by the Index on the Limb, which ſuppoſe 22°, 42; now I let the Teleſcope remain unmoved, till near the ſame diſtance from Noon in the afternoon, when I move the Index horizontally, without altering the Elevation of the Teleſcope, till the croſs-wires again both touch the edge of the Sun's body, but on the other ſide of the vertical wire; then I write down the degree and decimal now ſhewn by the Index, which ſuppoſe 173°, 62, and ſubtracting 22°, 42, the morning obſervation therefrom, the remainder is 151°, 2; the half of which 75°, 6 being added to 22°, 42 makes 98°, 02; to which I bring the Index on the Limb, then the Teleſcope will be in the *Meridian*, and if depreſt, will direct where a mark may be fixt, which from another fixt under the center of the Theodolite will be a *Meridian-Line*; but if the Sun is near the Equinox, there will be ſome material variation; and if near the other Tropick, or Winter Solſtice, his motion will be too oblique for a good obſervation; therefore a *Meridian-Line* may then be better found by a Star near the Equator, or having North Declination;

nation; but it had beſt not much exceed 20 degrees.

As the method of getting a *Meridian-Line* by obſerving any of the Stars near the Equator, is obvious, being like getting it by the Sun, except that the Star is to diſappear at the interſection of the croſs-wires in the firſt obſervation, and in the ſecond juſt appearing from behind it, and then if the Index is moved to the middle between the two obſervations, the Teleſcope will be in the *Meridian.*

But if more exactneſs is required than can be eſtimated on the Limb of the Theodolite, I take the time between the two obſervations by a good pendulum Clock; and then I let the Theodolite remain unmoved to the next night, with the Teleſcope at the ſame Elevation, when I again obſerve the ſame Star diſappearing at the interſection, from which, counting half the ſaid time by the Clock, the Star will then be in the *Meridian*, at which inſtant I ſet either edge of the upright wire to cut the Star; then depreſſing the Teleſcope, by the ſame edge I direct where a mark may be fixt, that from another fixt under the center of the Theodolite ſhall be a truer *Meridian-Line.*

Note, If a longer Teleſcope was fixt on the Theodolite for this purpoſe, the obſervations might ſtill be the truer.

Sect.

Sect. 6. *Shewing how to find the* Latitude *of the Place by the Theodolite, and by another Inſtrument, much truer, made for that purpoſe: Alſo a Table of the* Pole-Star's *greateſt Azimuth in ſeveral Latitudes; and remarks thereon.*

I plant and truly adjuſt my Theodolite as before; and knowing the Teleſcope to be truly level, when the flower-de-luce on the Double-Sextant cuts that on it's Index, and alſo to be nearly in the *Meridian*, I move the Double-Sextant vertically, till the lower edge of the horizontal wire in the Teleſcope cuts the lower edge of the Sun's body; then I write down the degree and decimal ſhewn on the Double-Sextant; now I make the upper edge of the ſame wire to cut the upper edge of the Sun, and write down the degree and decimal; now half the difference of theſe two, added to the former, is the Sun's *Meridian* Altitude, which leſſen'd by his Declination, if North, or increaſed by it, if South, abating the Refraction, is the *Co-Latitude* of the Place, which ſubtracted from 90° gives the *Latitude.*

But the moſt exact method of getting the *Latitude* with Mr. *Siſſon*'s Theodolite, is, by obſerving two Stars of equal Altitudes in the *Meridian*, the one North, and the other South, whoſe Declinations are known; for if the Northern Star is above the Pole, and the Southern above the Equator, half the difference

ence of their Declinations, added to the Declination of the latter, gives the *Latitude* of the Place.

But if the Northern Star is below the Pole, and the Southern above the Equator; then half the ſum of their diſtances from the Pole, added to the Declination of the latter, ſhall be the *Latitude* of the Place.

But if the Northern Star is below the Pole, and the Southern below the Equator; then half the ſum of their diſtances from the North Pole, leſſen'd by the Declination of the Southern Star, is the *Latitude* of the Place.

This laſt method being ſo limited, as not to be practiſed but in few Places, and there not at all times of the year, I would endeavour by experiment to know nearly the Angle of viſion that my Teleſcope takes in; then I may make a near allowance for the inequality of the Altitudes of any ſuch two Stars as ſhall happen within it's Area of viſion, whilſt the Teleſcope has the ſame Altitude in both parts of the *Meridian*.

But there is another method much more general, which is, by obſerving two Stars, whoſe Declinations are known, on equal Altitudes on each ſide of the *Meridian*, both North and South, with the true *ſidereal* time between the two obſervations of each Star: but as this requires a large Calculation, unleſs Tables be had of the *Verſed-ſines*, both natural and artificial, of which none yet extant are ſufficiently correct; I hope ere long to ſee a *third* Edi-

Edition of *Sherwin*'s *Mathematical Tables*; when I ſhall oblige the *Learned* with ſuch as are, having them already corrected by me, and ſhall give a *Solution* of this *Problem* with them (after a firſt approach made) at two Statings, the reſults of which ſhall prove one another, and alſo ſhew ſome other of their Uſes.

Mr. *Siſſon* has lately made another ſort of Inſtrument, with a longer Teleſcope, peculiarly adapted for this way of finding the *Latitude* of a Place, which moves more truly horizontal, and may alſo be ſet to any Elevation, whereby the Teleſcope is moveable with any certain Inclination, and will cut equal Altitudes all round, ſo that it will very accurately determine a *Meridian-Line* by the laſt paragraph of the former ſection, as well as the *Latitude* of the Place by this.

Note, A Day, or 24 hours, in *ſidereal* time is $3' : 55'' : 54'''$ leſs than a mean *Solar* Day of 24 hours equated time.

Some may chuſe to have larger and more coſtly Inſtruments, to get the *Latitude* of the Place, by obſerving the *Pole-Star*'s greateſt and leaſt *Altitudes*, and a *Meridian-Line* by her greateſt *Azimuths*; therefore I here print the following Table, and ſubjoin ſuch remarks as may prevent thoſe Perſons being any longer deceived, who take theſe obſervations at different times of the year, without making any due allowance for the alteration cauſed by the velocity of the *Earth*'s motion, having a ſenſible proportion with that of *Light*.

A Table ſhewing the greateſt Azimuth *or* Angle *that the* Pole-Star *makes with the* Meridian *in the Plane of the Horizon in any of theſe* Latitudes, *on the 22d of* Sept. 1737. *when the diſtance of the Star from the Pole will be* 2°: 5′: 37″. *See Mr.* Flamſteed's Hiſtoria Cœleſtis, *Vol.* III.

Latitudes		*Azimuths*			*Diff.*	
°	′	°	′	″	′	″
49	00 . .	3	11	31,7 . .		
					1	57,1
49	30 . .	3	13	28,8 . .		
					2	00,4
50	00 . .	3	15	29,2 . .		
					2	03,9
50	30 . .	3	17	33,1 . .		
					2	07,4
51	00 . .	3	19	40,5 . .		
					2	11,1
51	30 . .	3	21	51,6 . .		
					2	15
52	00 . .	3	24	06,6 . .		
					2	19
52	30 . .	3	26	25,6 . .		
					2	23,1
53	00 . .	3	28	48,7 . .		
					2	27,5
53	30 . .	3	31	16,2 . .		
					2	31,9
54	00 . .	3	33	48,1 . .		
					2	36,7
54	30 . .	3	36	24,8 . .		
					2	41,5
55	00 . .	3	39	06,3 . .		
					2	46,7
55	30 . .	3	41	53 . .		
					2	52
56	00 . .	3	44	45 . .		
51	32 . .	3	22	00,5 . .	*at London*	

Note, I have provided another Table of the *Pole-Star*, with ſuch remarks, that I can readily find the Time of it's being in the *Meridian*, or making it's greateſt *Azimuth*, with

 the

the alterations cauſed in both, by the ſwiftneſs of the *Earth*'s annual motion at all times throughout the year, for the preſent, and many ſucceeding years, and in the ſeveral above-mention'd *Latitudes*; all which I did intend to print herein; but have put it off for the preſent, being perſuaded that an Inſtrument might be made, at no very great expence, whereby (with theſe materials, and a good pendulum Clock) the obſervations of one year would certainly determine, whether thoſe of Mr. *Flamſteed* of the *Pole-Star* were near truth, or not; for I underſtand that None have yet pretended to correct them by new obſervations: now as the ſmall diurnal motion of this *Star* is ſo greatly diſturb'd by the ſwiftneſs of the *Earth*'s annual motion, of which Mr. *Flamſteed* had no ſuſpicion (tho' he obſerv'd the alteration, and aſcribed it to it's annual *Parallax*, and a *Nutation* of the *Earth*'s axis) it is wonderful that he could determine it's *Right Aſcenſion* and *Declination* ſo near truth as he has done: however, to pleaſure ſuch curious Perſons, who ſhall be willing to be at the expence of ſuch an Inſtrument, I will copy out in writing every particular here omitted, and perſonally explain each wanting it.

'*March* the 20th, and *Sept.* the 22d, the *Pole-Star* will have a juſt Elevation, either above or below the Pole, and her greateſt *Azimuth* true in proportion to her juſt diſtance from the Pole; but *June* the 21ſt, ſhe will appear 20″ too far from the Pole in any poſition, and *Dec.* the 21ſt, as

as much too near, whereby her greateſt *Azimuth* at *London* will be increaſed on the former 32″, and on the latter as much diminiſht; in greater *Latitudes* this alteration will be greater, and in leſſer *Latitudes* leſs; but will not always continue the ſame, for it will ſlowly leſſen, till the Star ſhall be in the *Solſtitial Colure*, at which time it will be near $\frac{1}{13}$ leſs, after which it will again increaſe to what it is at preſent, and be at the greateſt in the *Equinoctial Colure*, when at *London* it will be 32″ $\frac{1}{4}$, and is cauſed by the *Earth*'s annual motion having ſuch a proportion to that of *Light*, as the Sine of 20″ $\frac{1}{4}$ bears to the Radius; and the times will likewiſe alter, for in the year 2104 it's greateſt increaſed *Azimuth* will be on the 9th of *Sept.* and that the moſt diminiſht on the 7th of *March.*

As the Pole is moving on nearer to the *Star*, the ſeveral *Azimuths* will be continually leſſening; that for *London* in a mean rate till 1777 at 31″ $\frac{1}{2}$ yearly, and the others proportionably; but the rate will alſo decreaſe till *May* 2104, at which time the *Star* will be in the *Solſtitial Colure*, and neareſt to the Pole, when it's diſtance will be but 26′: 49″, according to Mr. *Flamſteed*'s obſervations; from which by a truer calculation the above *Azimuths* muſt *Sept.* 22. 1737 be a little increaſed, that for *London* by 6″ $\frac{1}{2}$; but if new obſervations ſhall determine truer, the time of the Table may be alter'd to fit.

CHAP. VI.

Shewing how to take the different Levels *of places by Mr.* Sisson's *New-invented Spirit-Level, and how to adjust the same, tho' put out of order, to a true level at any one Station; and also how to adjust the Telescope of his Theodolite to a true level.*

Sect. 1. *Containing a Description of Mr.* Sisson's *new Spirit-Level, as communicated by me to the* Royal Society *in* May 1736. *and of the Staves used in Levelling.*

THIS Spirit-Level stands on a three-legg'd Staff like his Theodolites, and the Telescope is in the same manner moveable, either in the Plane of the Horizon, or with a certain inclination to it, so as to cut any object, whose *Elevation* above or *Depression* below that Plane does not exceed 12 degrees: this Telescope is 18 inches long, with very fine cross-wires in the focus, whose intersection is evidently shewn to be in the axis of the Tube; for laying it in any manner on it's two Supporters, the object-glass

glaſs facing the ſame way, the interſection of the wires will conſtantly cut the ſame part of the object; and then if the object-glaſs being turn'd the contrary way, the Teleſcope is laid on the ſame Supporters, whilſt they remain unmoved, the ſame interſection will again cut an object placed in the ſame line with the former produced backwards.

To this Teleſcope is fixt by two ſmall ſcrews the Spirit-Tube, with a ſmall bubble of air included; and as this bubble reſts exactly in the ſame place, in or near the middle of the Tube, whether the object-glaſs be turn'd one way or the other, when laid on the ſame Supporters reſting unmoved, it is evident that the axis of the Teleſcope-Tube, which was before ſhewn to be in the interſection of the wires, is alſo in this caſe truly *level*; and hence the former aſſertion (that the Teleſcope turn'd backwards will cut an object placed in the ſame line, as it did forwards) appears true alſo; wherefore this Inſtrument may be called a *new* and *uſeful* Invention, as it is capable hereby of being adjuſted at any one Station, by obſerving one ſingle object, which it will determine at the ſame time to be in a true *level*; ſo that if by alteration of weather, or otherwiſe, the Inſtrument ſhall happen to be put from it's *level*, it may be readily reſtored and re-adjuſted at the firſt Station; which is an advantage no Inſtrument (that I know of) has before been capable of.

The beſt uſe of two Teleſcopes in the former Inſtru-

Inſtruments was, to know if either of them was out of the *level* by their diſagreement; but if it was not known which of the two was in fault, and that was the common caſe, there was the ſame trouble to bring either of them to it's right poſition, as if there had been but one; and it might beſides ſo happen, that both Teleſcopes agreeing in the ſame error, a *careful Surveyor* might be thereby deceived; whereas in this all poſſibility of being deceived is removed, and the obſervations are readily perform'd, which cannot with the ſame eaſe be done with the two Teleſcopes, becauſe they require two different adjuſtments of the air-bubble, and conſequently more time than *Surveyors* are always willing to beſtow on that purpoſe. The true reaſon indeed why ſo many Inſtruments have formerly been made with two Teleſcopes was, that their motion round not being perform'd near a true Plane, the one was commonly uſed to look forwards, and the other backwards, whilſt it ſtood in the line between the two objects, or vanes on the levelling Staves: but the ſame obſervations may with more accuracy and advantage be perform'd with one Teleſcope, as in thoſe Mr. *Siſſon* has made of late years, where that imperfection of the motion is obviated, ſince in this caſe the error (if there be any) is either diminiſht or deſtroy'd in the looking both forwards and backwards with the ſame Teleſcope; whereas with the two it may be increaſed in the two obſervations.

The

The two Supporters on which the Teleſcope of this New Spirit-Level is laid, are each nearly ſhaped like a capital Y, within the upper part of them the Teleſcope lies at reſt, and the two inner ſides of the Y in each Supporter are tangents to the *cylindrick* Tube of the Teleſcope, which is made ſo true a *cylinder*, that each touches it but in one place.

The lower end of theſe Supporters are let into a ſubſtantial braſs Plate, like that which carries the Sights of a Circumferentor, and ſo as to ſtand perpendicular to the Plate; below the bottom of one is fixt a fine ſcrew, to adjuſt the Tube when laid thereon to a true *level*, with an Index for knowing the true place; and to the other Supporter is applied a line of *tangents* as far as 12 degrees, whereby an Angle of either *Elevation* or *Depreſſion* may be taken to that extent.

On the upper ſurface of this braſs Plate (between the two Supporters) is fixt a Compaſs-Box, divided into 360 degrees, and numberd by 10, 20, *&c.* to twice 180, and again to four nineties, having a center-pin and Needle; ſo that it is in all reſpects a Circumferentor alſo, with the addition of all the 'foremention'd Improvements.

This Plate is fixt on ſuch a conical braſs ferril as the Compaſs Box of his Theodolites is fixt to; which ferril, like that, is fitted to the bell-metal fruſtum of a Cone at top of the braſs head (as in ſhort I may call it) of the three-legg'd Staff of the Theodolite, which has in

in it the ball and ſocket, with the three bell-metal joints, two ſtrong braſs plates, and the four ſcrews for adjuſting the horizontal motion, deſcribed more largely *page* 59: ſo that he who has one of the before-mention'd Theodolites, may have this fitted thereto; and the New-invented Protractor will agree with this alſo, when uſed as a Circumferentor; for this Inſtrument, tho' chiefly deſign'd for *Levelling*, is alſo well adapted for taking the Bearings by the Needle at the ſame time; ſo that the ſhape of a ſingle River might be plotted near enough by it; tho' it will not give the Bearings ſo true as needful, when deſign'd for the *Survey* of a *County*; becauſe, as I have already mention'd, the Needle is not to be depended on, where the whole muſt be plotted true, and meet in a point.

In *Levelling* we uſe two Staves ten feet long, in two parts each, that ſlide one by the other to 5 $\frac{1}{10}$ feet, for eaſier carriage, which are called Station-ſtaves; theſe are divided into 1000 equal parts, and number'd at every tenth diviſion by 10, 20, 30, *&c.* to 1000; there might alſo be another piece added to each, to increaſe them to fifteen feet, and ſo number'd on to 1500 each.

To each of the Staves a Vane is made to ſlide up and down, which by having ſprings will ſtand at any part of it, and when ſcrew'd will be immoveable; theſe Vanes are each made 30 parts wide, and 90 long; the width is firſt divided into three equal parts, and the

two

two extreams painted white; then the middle ſpace is again divided into three equal leſſer parts, the middle one of which is alſo painted white, and the two remaining ſmall parts are painted black; and thus they are fit for all common diſtances.

Sect. 2. *Shewing how to adjuſt the above-mention'd Spirit-Level at the firſt planting it, tho' juſt put together.*

Having planted the Spirit-Level, and adjuſted the horizontal motion on the conical fruſtum by the four ſcrews, which the Spirit-Tube will readily ſhew (like as in the Theodolite) if turn'd to three points nearly making right angles at the center to one another, and the Air-bubble keeps the ſame place, in or near the middle; for then it may be depended on, that the motion is truly horizontal; but if otherwiſe, it may ſoon be made to do ſo; for if the bubble is ſo, when the Teleſcope is directed to two points making right angles, and not at the third, then if I take off the Teleſcope, and lay it on the Supporters, as if to view the contrary way without moving them, and if the bubble then reſts in the ſame place, one end of the Spirit-Tube muſt be rais'd, and the other depreſt: but if the bubble moves to the contrary end of the Spirit-Tube, that is, towards the ſame Supporter of the Teleſcope, as it did before, then the Supporter having the fine ſcrew at bottom, muſt be rais'd or depreſt there-

therewith, till by the four ſcrews for adjuſting the horizontal motion, the bubble is made to reſt the ſame all ways, and then the motion will be truly horizontal.

The horizontal Motion being thus adjuſted, I take off the Teleſcope, and lay it on the Supporters, as if to view the contrary way, and if the bubble then reſts exactly the ſame, the Spirit-Tube and Teleſcope-Tube are both right.

Now I ſend an Aſſiſtant with one of the Station-Staves any diſtance at diſcretion, and make ſigns for him to ſet the Staff upright more to the right hand or left, as needful to appear within the Teleſcope, and to ſlide the Vane up and down, till it is cut exactly in the midſt by the horizontal wire in the Teleſcope, and then to ſcrew it faſt; now turning the Teleſcope to have the Spirit-Tube above it, if then the ſame wire (being horizontal) ſtill cuts the Vane exactly in the midſt, it is demonſtration, that the axis of the Teleſcope paſſing thro' the interſection of the croſs-wires is a true *Level*, and that the middle of the Vane is in the ſame *Level*.

Sect. 3. *Shewing how to adjuſt the Teleſcope of Mr.* Siſſon's *former Spirit-Levels, and that on his Theodolite, to a true* Level: *and a Table of the* Earth's *Curvature at ſeveral diſtances.*

I chuſe ſome ground nearly level of a ſufficient length, and plant either Inſtrument near the middle, ſuppoſe my Theodolite (which

may have a longer Teleſcope fixt over the ſhort one, parallel thereto, and alſo a long Spirit-Tube fixt thereon, parallel to that in the Double-Sextant, inſtead of the former Spirit-Level) and I make it by the four ſcrews to move round horizontally, which the Air-bubble in either Spirit-Tube will ſhew; for if that keeps the ſame place, in or near the middle, when ſet at right angles, but not at the oppoſite points, then one of the ſmall ſcrews under the Double-Sextant muſt be looſen'd, and the other tighten'd, till (by the four ſcrews adjuſting the horizontal motion) the bubble will keep the ſame moving all round; now I meaſure 633 links from the leaden ball under the center of my Theodolite one way, and there I leave an Aſſiſtant, with one of the levelling Station-Staves, and return to my Theodolite, and directing the Teleſcopes to the Staff, I cauſe him to ſlide up or down the Vane, till the horizontal wire in the upper Teleſcope cuts it exactly in the midſt, and then to ſcrew it faſt, in which poſition it muſt continue: now I meaſure 633 links the contrary way, and there I leave another Aſſiſtant with the other Staff, and return again to my Theodolite, which is now in the middle between the two Staves; then directing the Teleſcopes to this laſt Staff, I cauſe alſo this Aſſiſtant to ſlide his Vane up or down, till the horizontal wire in the ſame Teleſcope cuts it exactly in the midſt, and then to ſcrew it faſt, and continue it in the ſame poſition.

Now taking up my Theodolite, I plant it again to move horizontally close to that Staff, whose Vane seems distant from the ground such height, as the Telescope may easily be set at; for I set it (if possible) to have the axis of the Telescope I observe with, exactly of the same height as the lower edge of the middle white part of the Vane; but if I can't at either, then whatsoever difference there is in height between the axis of the Telescope, and the lower edge of the middle white part of the Vane, so much must the Vane on the other Staff be rais'd or lower'd; now directing the Telescope thereto, if the horizontal wire cuts it exactly in the midst, the Telescope is in a true *Level*; but if it does not, then the screws whereby it is fixt on the Double-Sextant, must one be loosen'd, and the other tighten'd, till it will do so; and then it will be adjusted to a true *Level*; for the Theodolite being now planted at the distance of 1266 links from the Vane, there must be the allowance of 1 $\frac{2}{3}$ parts, or divisions, on the Staff for the *Dip* by the *Earth's Curvature* (equal half the middle white part of the Vane) as may be known by the following *Table*, or latter *Note* below it; but if the Telescope is alter'd, the Spirit-Tube thereon must again be made parallel to that in the Double-Sextant; that is, the Air-bubble therein must by the screws be again brought to the middle between the marks.

A Table of the Quantities in the ſame Parts *as are number'd on the ten foot* Staves, *to be deducted out of the meaſures taken thereon in* Levelling, *at ſeveral diſtances truly number'd in* Links, *for the* Dip *by the* Curvature *of the* Earth.

Diſt. in Links	*Parts to deduct*	*Diſt. in Links*	*Parts to deduct*	*Diſt. in Links*	*Parts to deduct*
311	0,1	2193	5,0	3101	10
693	0,5	2300	5,5	3253	11
981	1,0	2402	6,0	3397	12
1201	1,5	2500	6,5	3535	13
1387	2,0	2595	7,0	3669	14
1551	2,5	2686	7,5	3798	15
1699	3,0	2774	8,0	3923	16
1835	3,5	2859	8,5	4161	18
1961	4,0	2942	9,0	4386	20
2080	4,5	3023	9,5	4600	22

Note, This Table may ſerve for any diſtance wanted; for the intermediates are had near enough by inſpection; and for greater diſtances, I multiply the *Parts* by the ſquare of that number, which multiplying a tabular diſtance will produce the given diſtance: ſuppoſe the diſtance 92 chains, then $46 \times 2 = 92$, and $22 \times 4 = 88$ *Parts* for the *Dip*.

Note

Note alſo, The ſquare of the diſtance in chains multiplied by 104, cutting off the four right hand figures for decimals, will give the quantity in *Parts* of the Station-Staves very little more than the truth.

Sect. 4. *Shewing how to take the difference of* Levels *between two places, and to allow the* Dip *for the* Earth's Curvature, *where many Stations muſt be made, being of uſe in conveying* Water, *&c.*

Let it be required to know what fall there is for *Water* to run from a Spring-head to any determined Place.

I may begin at either, but will ſuppoſe at the Spring-head; where having the New-invented Spirit-Level, two Aſſiſtants with the two Station-Staves, my Chain, Arrows, and a Boy to carry the Spirit-Level, I cauſe one Aſſiſtant to ſet up his Staff upright, with the lower end touching the ſurface of the *Water* at the Spring-head; now with the other Aſſiſtant I meaſure on to where I judge proper, for firſt planting my Spirit-Level, as to 311 links, which I write down in the firſt column under *Diſt.* then planting my Spirit-Level to move horizontally, I direct the Teleſcope to the Staff, and obſerving the bubble to be exactly between the marks, make ſigns to that Aſſiſtant to ſlide the Vane up or down, till the horizontal wire in the Teleſcope cuts it exactly in the midſt, and then

to

to fix it; now he brings it to me, and I write down in the ſecond column againſt 311 the number of *Parts* on the Staff at the upper edge of the Vane, *viz.* 247, under *Parts*, and in the mean time my other Aſſiſtant goes forward with his Staff, and ſets it up where I make a ſign to him to ſtop, and then he ſlides the Vane up or down, and fixes it according to the ſigns I make, when the ſame wire cuts it alſo in the midſt; now the Boy takes the Spirit-Level and Staff, whilſt my firſt Aſſiſtant leads the Chain for my meaſuring on to the ſecond, whoſe diſtance I find 693 links, which I ſet down in the fourth column under *Diſt.* or firſt under *Fore-Sights*, and againſt it in the next column I write 376, the number of *Parts* on the Staff at the upper edge of the Vane; the ſame Staff being ſtill kept erect touching the ground in the ſame place, I meaſure on to the place for next planting my Spirit-Level, *viz.* 981 links, and write it down in the firſt column juſt under 311; now planting my Spirit-Level, and obſerving as before, and the Staff brought to me, I find the upper edge of the Vane at 313 *Parts*, which I ſet down in the ſecond column under 247; now I obſerve again forward, which Vane being fixt, I meaſure thereto as before, and find the diſtance 1201 links, which I ſet down under 693, and againſt it in the next column 543, the *Parts* at the upper edge of the Vane, juſt under 376; and thus I proceed on in meaſuring,

obſerv-

obſerving, and writing down, tho' there ſhould be never ſo many Stations, till the forward Staff is ſet up at the determined Place for my laſt obſervation, and that diſtance, and the *Parts* wrote down alſo; then the work abroad is finiſht.

Being come home, I deduct the quantities of *Dip* for the *Earth's Curvature*, according to the foregoing *Table*, and in the third and fixth columns under *correct* I write down the true corrected quantity of *Parts*, that are to be accounted in *Levelling*.

The Form of the Field-book in Levelling.

Back-Sights.			*Fore-Sights.*		
Diſt.	*Parts*	*correct*	*Diſt.*	*Parts*	*correct*
311	247	246,9	693	376	375,5
981	313	312,0	1201	543	541,5
1387	795	793,0	1119	854	852,7
512	172	171,7	1551	785	782,5
1699	374	371,0	597	678	677,6
610	219	218,6	1835	947	943,5
1200	137	135,5	774	876	875,4
The Sum		2248,7	The Sum		5048,7

Now I ſubtract the Sum of the Back-Obſervations from the Forward, and the remainder 2800 *Parts* equal to 28 Feet, is the true

true difference of *Levels*; and becauſe the Sum forward is greater than the backward, there is that fall for the *Water* to run.

Note, Authors ſay, that *Water* will have a ſmall current with the fall of 4 ½ inches for every Mile; but if the fall is too great, the way may be increaſed, and the motion retarded by being crooked with many turnings, and broad places narrow again on a ſudden, which broad places will be ſo many *Reſervoirs* for preſerving the *Water*.

Sect. 5. *Shewing how to take the difference of* Levels *in a gradual* Aſcent *or* Deſcent, *where by planting the Spirit-Level in the middle between, or any other part, the Vanes on the Station-Staves may be ſeen both at top and bottom.*

Firſt, I ſuppoſe my Spirit-Level planted in the middle between, or at the ſame diſtance, *viz.* 879 links, from the two Staves ſet upright, one at the top, and the other at the bottom, and that the Vanes are both fixt on the Staves at the ſame diſtance from the ground as the Axis of the Teleſcope; tho' it may be otherwiſe, if needful; but then the difference muſt be accounted.

Now I adjuſt my Spirit-Level to move round horizontally, and then I direct the Teleſcope to one of the Staves (ſuppoſe the upper) by raiſing the Supporter, that has the line of *Tangents*, and then I let it down

again, to ſee if the bubble will ſettle exactly between the marks on the Spirit-Tube, or if not, I make it do ſo, with the fine ſcrew under the other Supporter; now I elevate it again by raiſing the former Supporter, till the horizontal wire in the Teleſcope cuts the Vane exactly in the midſt, and then I ſcrew faſt the Supporter, and the line of *Tangents* ſhews the Angle of *Altitude*, *viz.* 7° : 27′.

Now I take off the Teleſcope, and lay it on to view the contrary way, and direct it to the lower Staff; then I let down again the rais'd Supporter, to ſee if the bubble ſettles again exactly between the marks; now I depreſs again the Teleſcope by raiſing the ſame Supporter, till the horizontal wire cuts this Vane exactly in the midſt, and then I ſcrew faſt the Supporter, and the line of *Tangents* ſhews alſo the Angle of *Depreſſion*, *viz.* 6° : 57′.

To ſolve this, it is beſt to have Trigonometrical Tables, of which none now extant are ſo truly corrected as the *ſecond* Edition of *Sherwin's Mathematical Tables*, for which I collected a ſmall *Errata*, that includes all the material Errors in the whole, except the *Traverſe* and *Verſed-Sines*; for the laſt of theſe are ſo erroneous in Sir *Jonas Moor's* Syſtem, from whence they were copied, that the number would have made the ſaid *Errata* too large; therefore the Bookſeller refuſed printing thoſe in the *Errata:* but I have corrected

rected every *Number* thro' all the Tables, to the greateſt exactneſs poſſible, in that book, which I have prepared for the *third* Edition, and is in my own poſſeſſion; and I do intend to put therein the *Logarithmick Sines* for every *Second* of the firſt ſixty-four *Minutes*, with directions to take out the *Tangent*, *Co-Tangent*, and *Co-Secant* therefrom, and all of them with the *Verſed-Sines* for every two *Seconds* to double that extent, whereby they will be made the compleateſt *Set* to ſeven decimal places that were ever publiſht. The ſaid *Tables* of the *ſecond* Edition, with the *Errata*, may be had of Mr. *Siſſon*, and the other Publiſhers of this Book.

A Solution of the foregoing Example.

First, As Radius to 879 links = Log. 2,9439889
So is the Sine of 7°: 27′ = Log. 9,1128092

To the Perpend. 113,97 = Log. 2,0567981

Second, As Radius to 879 links = Log. 2,9439889
So is the Sine of 6°: 57′ = Log. 9,0827966

To the Perpend. 106,36 = Log. 2,0267855
Add firſt Perpend. 113,97

The Sum 220,33 links,
which reduced is 145,42 Feet nearly for the true difference of *Levels* between the top and the bottom.

Note, Being at the ſame diſtance from each in the ſlope-lines, the *Dip* of the *Earth's Curvature* is very nearly alike in both, which is the reaſon, that *Surveyors* in *Levelling* endeavour always, as near as they can gueſs, to place their Inſtrument in the middle between the two Station-Staves: but the *Table* will ſhew, that in long diſtances they may be liable to much error, without meaſuring, and allowing for the *Dip.*

Secondly, I ſuppoſe this gradual *Aſcent* and *Deſcent* to be a Road with a turning in it, where the Spirit-Level muſt be planted, to ſee to the top and bottom.

The Vanes being on both Staves fixt the ſame height from the ground as the axis of the Teleſcope, and the Angles of *Altitude* and *Depreſſion* taken the ſame as in the former Example, I proceed to meaſure the lengths of the ſlope-lines, from the leaden ball touching the ground directly under the center of the Inſtrument, to the bottom of each Station-Staff, and I find that upwards 1374 links, and that downwards 698.

A Solution of this ſecond Example.

First, As Radius to 1374 links = Log. 3,1379867
So is the Sine of 7°: 27′ = Log. 9,1128092

To the Perpend. 178,154 = Log. 2,2507959

Second,

Second, As Radius to 698 links = Log. 2,8438554
So is the Sine of 6° : 57′ = Log. 9,0827966

To the Perpend. 84,46 = Log. 1,9266520
Add firſt Perpend. 178,154

The Sum 262,614 links,
which reduced is 173,326 Feet, from which
I take for the diff. of *Dips* of the *Curvature* } 0,014
Differ. of *Levels* 173,312 Feet.

Note, In taking the *Dips* of the *Earth's Curvature*, I reduce the ſlope-lines to horizontal by the Table *page* 68.

Note alſo, Mr. *Siſſon*'s new circular Inſtrument, of which I have prepared a ſmall *Treatiſe*, will ſolve theſe Examples with certainty, and near enough to truth in the buſineſs of *Levelling*.

THE END.

NOBLEMEN's and GENTLEMEN's ESTATES Survey'd and Plotted in the moſt Exact Manner hitherto uſed, and Books of the Particulars drawn therefrom,

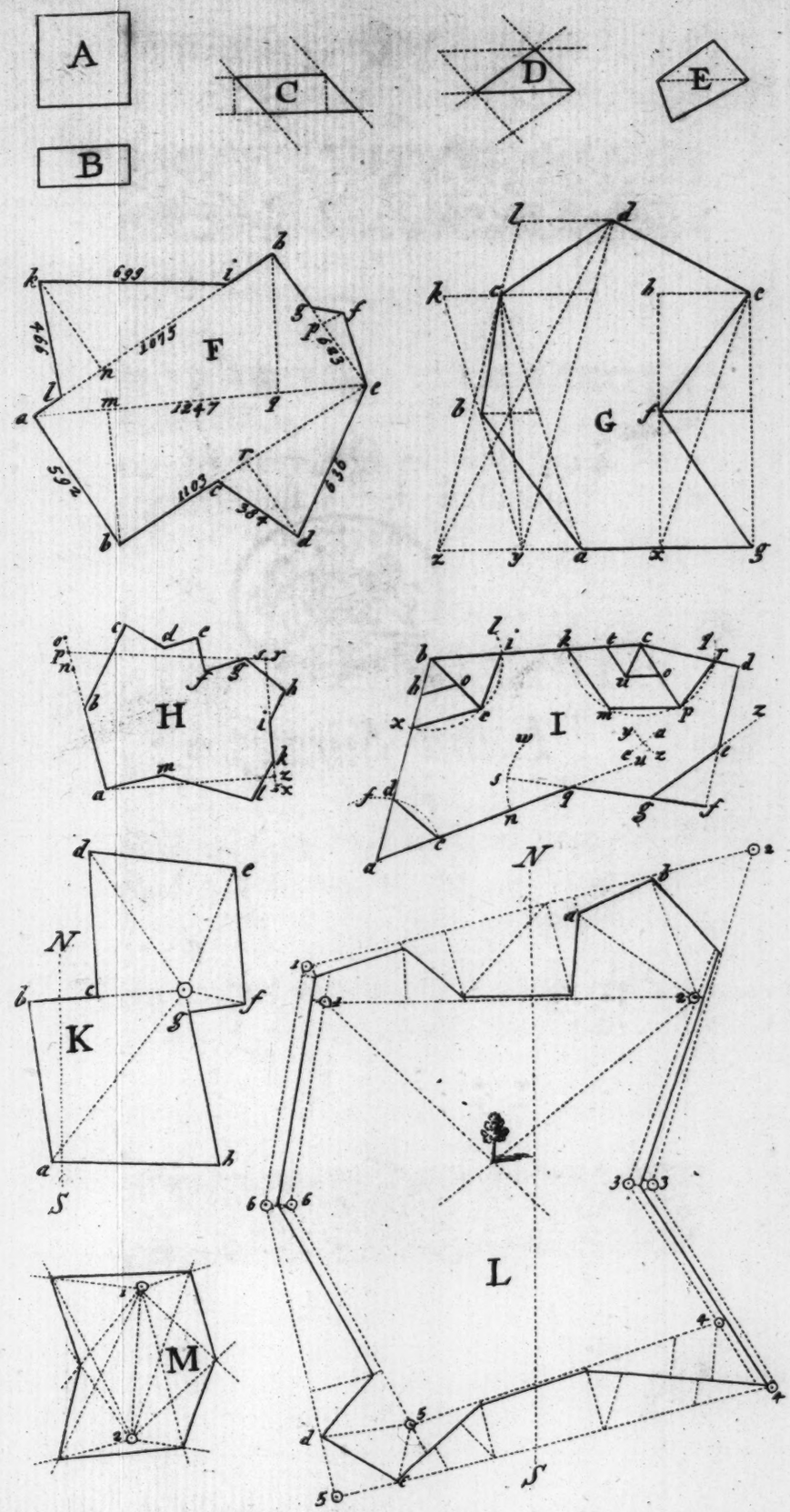
BY

WILLIAM GARDINER,

Land-Surveyor:

Who may be heard of at Mr. *Siſſon's*, Mr. *Betteſworth's*, or at *Richard's Coffee-Houſe Temple-Bar.*

NB. At each Place may be ſeen a Specimen of his fair Plans.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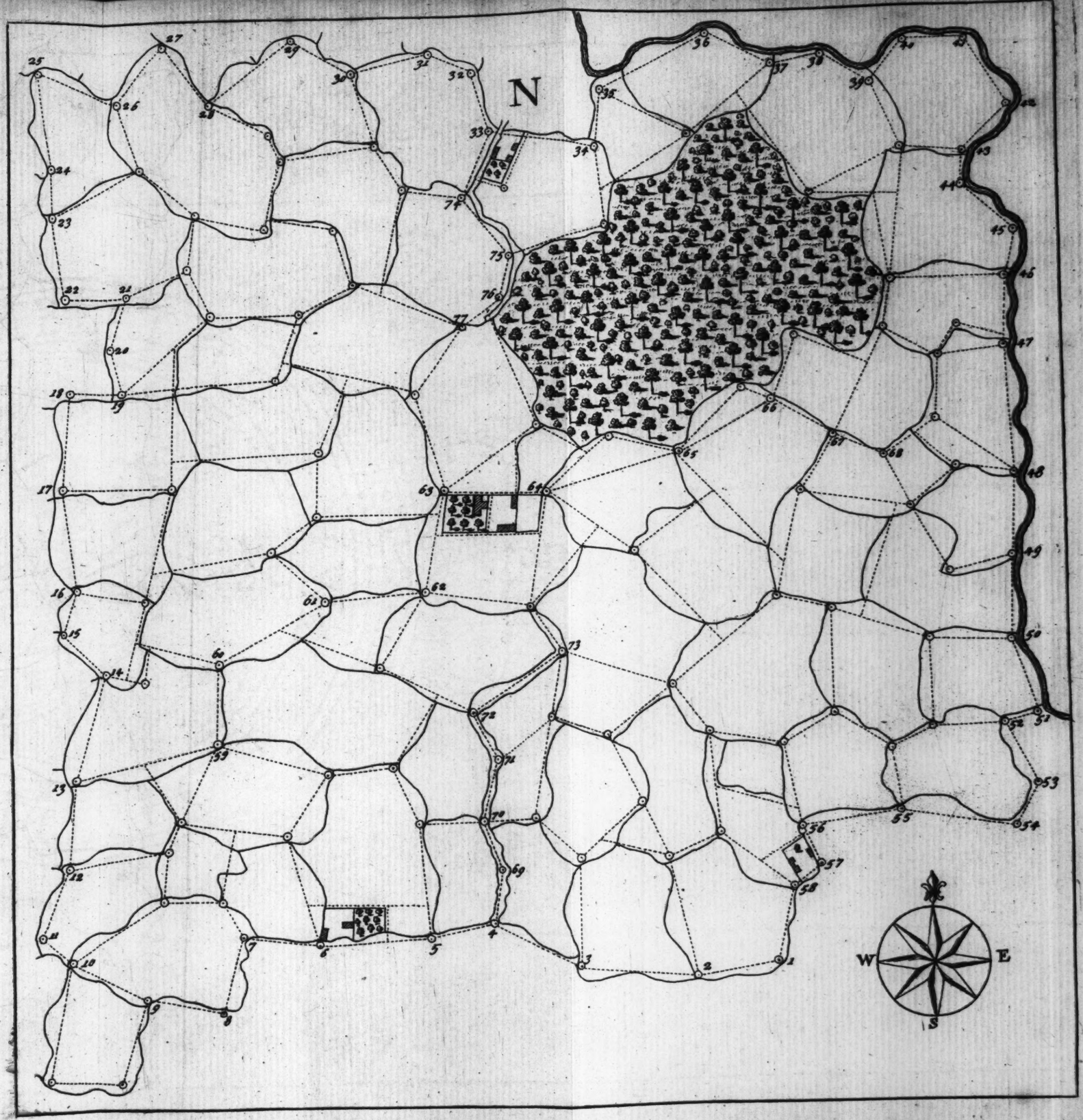
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